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AIR POLLUTION-LAND USE PLANNING PROJECT

Phase I. Final Report: July 1971

by

Allen S. Kennedy, Alan S. Cohen,
E. J. Croke, K. G. Croke,
J. Stork, and A. P. Hurter

ARGONNE NATIONAL LABORATORY

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Center for Environmental Studies

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ABSTRACT

Environmental-control activities can be expected to influence and be influenced by urban and regional development. It is appropriate to seek a means by which the environmental systems analyst can function effectively within the broader context of urban and regional development planning. We suggest that land use represents the most convenient, and potentially one of the most viable, interfaces between environmental control and regional-development analysis. In particular, it offers a means of integrating air-resource management with urban and regional-development planning and related public-investment programs. Consequently, the fundamental assumption of the Air Pollution-Land-Use Planning Project has been that land use provides a framework on which techniques for designing, evaluating, and implementing control strategies can be based. This report presents methods and procedures that can be used to assess the air pollution potential of land-use plans and discusses methods by which air pollution considerations can be introduced into the planning process.

1. GENERAL INTRODUCTION

1.1 Land Use as a Basis for Air Resource Management

The objective of air pollution control planning programs, as now represented by Federal implementation plan guidelines, is to meet and maintain the Federal air quality standards. Although control regulations can presently be tested (with dispersion models) to determine whether regulations are sufficiently stringent to meet these air quality standards, control strategies designed in this fashion fail to account for changing urban patterns and growth in regional economic activity. Methods for projecting and controlling spatial emission patterns due to land-use development and economic growth have yet to be developed.

Since such environmental control activities can be expected to influence and be influenced by urban and regional development, it is appropriate to seek a means by which the environmental systems analyst can function effectively within the broader context of urban and regional development planning. We suggest that land use represents the most convenient, and potentially one of the most viable, interfaces between environmental control and regional development analysis. In particular, it offers a means of integrating air resource management with urban and regional development planning and related public investment programs. Consequently, the fundamental assumption of the Air Pollution-Land-Use Planning Project has been that land use provides a framework on which techniques for designing, evaluating, and implementing control strategies can be based.

Viewed in the context of the regional development, environmental protection planning and its array of analytical techniques appears in proper perspective--as a subcategory of the much broader and more comprehensive field of urban and regional development planning. While air pollution control planners are ready enough to acknowledge, in principle, their professional kinship with regional economists, geographers, demographers, planners, and transportation systems analysts, the most sophisticated air pollution implementation plans developed to date are dominated by traditional, technology-oriented regulatory practices which focus on the control of existing sources through registration and permit systems, coupled with comprehensive surveillance and monitoring programs.

Although such activities are undoubtedly necessary, they fail to take account of the economic and demographic factors and development trends which have led to environmental degradation. These include the tendency of industrial and commercial activities toward spatial concentration, the migration of industry under the impetus of improved transportation technology, the growth and redistribution of population which results from natural increase and interregional migration, and changing demands for

the factors of production, including capital equipment, land, energy, labor, and natural resources. It is likely that these phenomena will ultimately determine whether environmental protection represents a viable kind of constraint on urban and regional development.

Perhaps the most obvious hazard associated with a failure to integrate environmental protection planning with regional planning is the potential obsolescence of control regulations as redevelopment of urban core areas, rapid growth in metropolitan fringe areas (stimulated by improved transportation facilities) and the development of new towns proceeds. Of equal importance, however, is the fact that traditional, technology-oriented control programs are inherently incapable of exploiting such potentially powerful long-range modes of control as land-use planning and zoning, tax incentives and selective public investment programs.

1.2 Review of the Objectives of the Air Pollution-Land-Use Planning Project--Phase I

The objectives of the first phase of the Argonne Air Pollution-Land-Use Planning Project were as follows:

- 1) Develop a land-use computer submodule of the Air Quality Display Model (AQDM) System. This submodule is to contain provision for the input of land-use data in a standard format, the estimation of spatial emission patterns, and the computation and output of air quality displays in standard AQDM format. These displays will indicate the air quality which will result if the projected land-use pattern in the region is realized.
- 2) Provide techniques for evaluating the effect of proposed emission control strategies on the air quality given a projected land-use plan in a region.
- 3) Test the land-use plan environmental submodule using data from the Chicago Air Quality Control Region.
- 4) Provide a procedure for evaluating land-use-based emission density regulations and test the procedure on the Chicago Air Quality Control Region.

This report describes the methods and procedures used in accomplishing these task items and documents the results obtained by applying these techniques to the Chicago region.

1.3 Report Overview

Although the Phase I effort resulted in the achievement of the objectives listed above, we believe the work uncovered many areas where

further research is warranted. These problem areas are identified in the body of the report and many will be pursued under Phase II of the project.

One way of summarizing the land-use air pollution program is shown in the flow diagram of Fig. 1.1. The major sections of this report have been

Fig. 1.1. Components of a Land-Use-Based Control Strategy Design, Evaluation, and Implementation Process

organized around the components of a land-use-based air quality control strategy design, evaluation, and implementation process as shown in the figure.

The process begins by assuming a land-use plan has been specified for the region under consideration. This plan usually represents local community preference for land development and is generally enforced by a zoning ordinance. Current emission files and economic growth projections are used to develop emission density factors (e.g., tons/day/mi²) by land-use classification. These factors coupled with a projected land-use plan indicate future emission patterns. (Alternative methods for generating land-use-based emission maps are discussed in Section 2.)

The method for transferring these emission patterns into air quality projections is discussed in Section 3. The procedure uses the standard AQDM dispersion model. Samples of projected air quality for the Chicago region are developed and displayed in this section as well as a discussion of the difficulties in applying dispersion modeling to land-use-based projections.

Alternative control strategies are discussed in Section 4. Types of strategies include the traditional point source regulations, land-use-based emission density limits, indirect inducements such as tax/subsidy programs and public investment projects, and alteration of land-use developmental plans. Each of these methods directly or indirectly impacts the locational decisions of economic units and hence the spatial emission patterns. These controlled emission patterns can be evaluated by the dispersion model in conjunction with a strategy selection model.

After a set of feasible strategies has been determined, the choice must be narrowed by the application of economic, political, and administrative criteria, and institutional mechanisms must be developed for implementing the strategies that make up the final control program. These topics are discussed in Section 5 of the report.

2. DEVELOPMENT OF A LAND-USE-BASED EMISSION INVENTORY

2.1 Introduction

The spatial distribution of pollutant emissions in an urban region depends on many variables, including the type and intensity of activity located on a particular plot of land, the age of the establishment, transportation systems serving the area, etc. Ideally, for air pollution purposes, land use would be classified by the emission potential of the activity or activities encompassed by the class designation. That is, reasonable emission densities could be ascertained by simply knowing the land-use class located on a plot of land.

Projections of such future emission patterns must be made on the basis of estimates of emission densities for any given land-use classification. These emission density factors, together with a land-use or zoning plan, form the inputs for a dispersion model for the purpose of predicting future air quality and assessing its change due to regional growth development. The process is outlined in Fig. 2.1.

Fig. 2.1. Land-Use-Based Air Quality Projection System

There are many ways of developing land-use emission density factors. Aggregation can be performed on such parameters as zoning classes, activity levels, activity types, and/or energy or fuel usages. During the first phase of the Air Pollution-Land-Use Planning Project, three different approaches of land-use-based emission density factor development were analyzed.

1) The development of emission density factors and projections based on a zoning land-use classification.

2) The development of emission density factors and projections based on the present location and composition of SIC activities in a region.

3) Prediction of future emissions based on economic activity related emission factors.

Each method depends on the use of a modified form of the basic dispersion equation. Assume that E^m represents the expected emission density

(in tons/day/acre, or some analogous units) for land-use class m . Then, given that the known or specified percentage of land designated for land-use class m in area A_ℓ is given by F_ℓ^m , the expected regional air quality can be computed from

$$\chi_k = \sum_m E^m \left(\sum_\ell \alpha_{\ell k}^m A_\ell F_\ell^m \right) + \beta_k, \quad (2.1)$$

where

χ_k is the concentration at point k ,

$\alpha_{\ell k}^m$ is the dispersion transfer "coefficient" (assuming linearity) describing the contribution of a unit emission from land-use class m in location ℓ to the concentration at location k ,*

A_ℓ is the land area in grid square ℓ ,

and

β_k is the background concentration at location k .

2.2 Estimation of Land-Use Emission Factors Based on Zoning

Projections regarding the degradation or improvement of the regional air quality necessarily involve estimates of future land/space use. These estimates can be obtained from local zoning ordinances, regional planning agencies, or land-use models. The techniques pursued during Phase I of the Air Pollution-Land-Use Planning Project assume a zoning or land-use plan has been specified and meaningful emission densities can be projected in terms of the land-use variables that describe the plan (tons/day·mi² for a given land-use activity). For example, a medium residential classification implies an average number of dwelling units, and expected fuel use, and hence an expected emission pattern. In dealing with the emission density estimation problem, one may either develop average emission density values or generate probability distributions of the amount of pollutant emitted.

Basic to what follows is the assumption that present or projected land use can be represented by a zoning inventory. A zoning inventory was collected at Argonne for the Chicago Region on a square-mile basis and computerized as fractions of land area zones for each land-use class. The computerization was also done to be compatible with the Chicago Region AQDM area source emission inventory. The following land-use classes were identified:

- 1) Heavy industrial (by definition all point sources in the emission file except power plants which are left as point sources because of their size);

*Note that although concentration levels are dependent on current meteorological conditions, the Martin-Tickvar AQDM dispersion model^{1,2} used here computes a daily expected contribution by weighting the contribution due to varying meteorological conditions by their frequency of occurrence in the region. Also, contributions from various land-use classes depend on the physical emissions parameters of the source (stack height, stack diameter, exhaust velocity, and temperature). Since varying classes have different emission characteristics, a contribution factor for each class must be calculated using the appropriate average characteristics.

2) Light industrial;

3) Large (or heavy) residential and commercial (i.e., Chicago "loop" office buildings, high rise areas, heavy residential coal-use areas, outlying downtown centers, etc.).

The procedure used to collect and store the zoning inventory is discussed in Appendix A.

The zoning classification approach for developing land-use-based emission factors organizes emission information on the basis of zoning classifications (e.g., heavy industry). From this information maximum expected emission densities (E^m) are generated. Using these land-use emission factors (E^m) in Eq. 2.1 can yield the maximum or worst expected air quality that could occur based on the given projected growth limitations due to zoning. The model does not indicate when and if this level of growth will actually occur in the future. For example, the worst situation may be a region with only steel mills located in areas zoned for heavy industry.

To estimate emission densities by zoning class, a program was prepared to aggregate emissions on a square mile grid and list them in decreasing order of both actual emissions and emission densities ($\frac{\text{actual emissions in class}}{\text{land zoned in class}}$). This was accomplished for the largest 300 square miles in the region. This program is described in Appendix B and the results for the Chicago Region are summarized in Tables 2.1 and 2.2.

It is immediately evident that because of the large variations in emission density, especially in the heavy industrial class, stable estimates of

TABLE 2.1. Chicago Region Emission Densities^a by Square Mile
(largest 300 miles--1968 emission inventory)

Zoning Class	Pollutant	Max	Mean ^b	Min	Percent of Total Emissions
Total	SO ₂	555.43	16.1	2.74	91.8
	Part	509.03	9.7	1.27	93.4
Heavy Industrial	SO ₂	772.2	9.9	0	100
	Part	507.3	5.4	0	100
Light Industrial	SO ₂	40.6	5.2	1.1	82.5
	Part	21.9	2.7	0.56	73.9
Large Residential Commercial	SO ₂	28.4	1.25	0	100
	Part		0.55	0	100

^aTons/day/mi².

^bComputed as $\frac{1}{300} \sum_{i=1}^{300} \left(\frac{E_i^m}{Z_i^m} \right)$, where E_i^m - emissions in class m, Z_i^m - zoning in class m.

TABLE 2.2. Chicago Region Emissions^a by Square Mile
(largest 300 miles--1968 emission inventory)

Zoning Class	Pollutant	Max	Min	Percent of Total Emissions
Total	SO ₂	169.17	0.52	96.2
	Part	152.71	0.25	96.3
Heavy	SO ₂	168.2	0	100
Industrial	Part	152.2	0	100
Light	SO ₂	4.33	0.12	90.8
Industrial	Part	1.90	0.07	86.1
Large	SO ₂	11.6	0	100
Residential	Part	4.85	0	100
Commercial				

^aTons/day.

projected emissions cannot be made in this manner.* The problem is that zoning classifications as defined bear little consistent relationship to the emissions being produced. To correct the problem for projection purposes would require a redefinition of the land-use or zoning classifications to more closely describe probable environmental effects. It must be kept in mind, however, that more refined classifications will require more data. The coarse zoning classification has the advantage of requiring only data currently being collected during the implementation planning process.

2.3 Predictions of Emissions Based on a Growth in Place Approach

A second alternative to emission estimation is to assume economic growth does not alter the composition or location of pollution sources and can be conceived of as a secular trend in the emission rates of present polluters. Regional economic growth projections by SIC classification** were prepared and reported by the Regional Economics Division of the Department of Commerce for the EPA.⁴ These growth factors are applied to each point source in the current emissions file by SIC class under the assumptions that growth capacity will be added to or near existing facilities and that existing facilities all grow at this same average rate. (Note that the conversion of residential space heating from coal to gas can be incorporated by inputting a decay factor.) This new projected emission source inventory can be aggregated on a square-mile or AQDM-area-grid-square basis as before.

*These results are similar to those reported by Bunyard and Williams³ in their study of the St. Louis Region.

**The Standard Industrial Classification (SIC) System is a commonly used coding assigned to various types of industrial activity for identification and record-keeping purposes. Table 2.3(a) shows major source category readings and code numbers.

TABLE 2.3(a). Major SIC Classification Descriptions

Class Title	SIC	Class Title	SIC
Food and kindred products	20	Rubber and plastic	30
Tobacco manufacturing	21	Leather products	31
Textile mills	22	Stone, clay, glass, concrete	32
Apparel and fabrics products	23	Primary metals	33
Lumber products	24	Fabricated metals	34
Furniture and fixtures	25	Machinery	35
Paper products	26	Electrical machinery	36
Printing and publishing	27	Instruments	38
Chemical products	28	Miscellaneous manufacturing	39
Petroleum refining	29	Electric and gas services	49

The assumption of growth in place has a great deal of validity because it is well known that certain industries tend to aggregate in a given location for reasons such as labor availability, transportation facilities, etc. New growth will thus be located near older facilities for such industries. This assumption breaks down, of course, when entirely new industrial developments are introduced or existing facilities expand disproportionately. The "Sag canal strip," located in Will County, southwest of Chicago near Joliet is a good example of such a developing area. We could allow for the designation of such newly developed areas in the program, but the rules used to allocate a share of projected emissions to such areas is still a problem we have not resolved. The solution to the new development problem would probably have to utilize some sort of land-use projection model.

Table 2.3(b) shows the economic growth factors for 1980 for the Chicago Region from the economic projection report. Tables 2.4(a) and (b) show sample emission data by AQDM grid for 1968 and 1980 emission estimates using these SIC growth rates.

TABLE 2.3(b). Growth Factors for Chicago Air Quality Control Region for 1980

(fraction of 1968 emissions)

SIC	Factor	SIC	Factor	SIC	Factor
20	1.29	27	1.43	34	1.44
21	1.73	28	1.72		
22	1.27	29	1.62	35	1.44
23	1.30	30,31	1.75	36	1.74
24,25	1.56	32	1.46	38,39	1.73
26	1.67	33	1.40	49	1.53

TABLE 2.4(a). Illinois-Chicago Region--1968 Emissions by Area

SOURCE DATA												
	SOURCE NUMBER	SOURCE LOCATION (MILES)		SOURCE AREA SQUARE MILES	ANNUAL SOURCE EMISSION RATE (TONS/DAY)		STACK DATA				SOURCE CLASS	
		HORIZONTAL	VERTICAL		SO ₂	PART	HT (FT)	DIAM (IN)	VEL (M/SEC)	TEMP (DEG. K)		
Power Plants	1	20.4	23.9	0.0	171.500	1.300	137.3	4.1	40.5	464.	4911.	
	2	20.4	23.9	0.0	89.500	39.000	75.6	3.5	13.4	464.	4911.	
	3	19.9	23.9	0.0	570.000	18.500	168.0	5.3	36.6	464.	4911.	
	4	37.8	45.1	0.0	84.000	1.880	65.0	3.0	36.6	464.	4911.	
	5	37.6	84.7	0.0	258.000	16.930	125.0	4.3	29.6	464.	4911.	
	6	23.3	33.4	0.0	150.010	6.450	105.5	4.0	18.3	464.	4911.	
	7	23.3	33.5	0.0	316.500	12.320	145.6	4.7	27.5	464.	4911.	
	8	51.0	38.2	0.0	375.000	1.140	116.0	7.3	5.5	464.	4911.	
	9	71.5	33.4	0.0	28.500	0.118	122.0	5.6	45.1	430.	4911.	
	10	57.0	33.3	0.0	267.000	5.400	72.0	6.0	24.9	416.	4911.	
	11	42.5	54.2	0.0	0.0	0.0	100.0	4.3	6.5	464.	4911.	
	12	44.6	48.1	0.0	89.800	1.797	96.0	5.1	13.2	464.	4911.	
	13	44.6	48.1	0.0	116.700	3.892	147.5	6.0	13.0	464.	4911.	
	14	41.1	46.5	0.0	303.299	11.210	124.7	3.4	42.7	464.	4911.	
Heavy Industry	15	50.0	38.4	0.0	22.220	1.972	100.0	2.6	12.9	464.	4911.	
	16	46.0	51.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.	
	17	45.0	51.0	1.00	0.310	0.370	39.0	5.8	2.3	473.	9999.	
	18	44.0	51.0	1.00	3.670	2.687	39.0	5.8	2.3	473.	9999.	
	19	43.0	51.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.	
	20	42.0	51.0	1.00	0.550	0.296	39.0	5.8	2.3	473.	9999.	
	21	46.0	50.0	1.00	4.040	2.499	39.0	5.8	2.3	473.	9999.	
	22	45.0	50.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.	
	23	44.0	50.0	1.00	0.0	0.885	39.0	5.8	2.3	473.	9999.	
	24	43.0	50.0	1.00	0.0	0.548	39.0	5.8	2.3	473.	9999.	
	25	42.0	50.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.	
	26	46.0	49.0	1.00	0.265	0.011	39.0	5.8	2.3	473.	9999.	
	27	45.0	49.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.	
	28	44.0	49.0	1.00	0.0	0.233	39.0	5.8	2.3	473.	9999.	
	29	43.0	49.0	1.00	0.0	0.186	39.0	5.8	2.3	473.	9999.	
30	42.0	49.0	1.00	0.0	0.239	39.0	5.8	2.3	473.	9999.		
31	46.1	48.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.		
32	45.0	48.0	1.00	1.830	2.160	39.0	5.8	2.3	473.	9999.		
33	44.0	48.0	1.00	0.0	1.726	39.0	5.8	2.3	473.	9999.		
34	43.0	48.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.		
35	42.0	48.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.		
36	45.0	47.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.		
37	45.0	47.0	1.00	0.480	0.189	39.0	5.8	2.3	473.	9999.		
38	44.0	47.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.		
39	43.0	47.0	1.00	0.0	0.940	39.0	5.8	2.3	473.	9999.		
40	42.0	47.0	1.00	9.016	4.627	39.0	5.8	2.3	473.	9999.		
41	47.0	46.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.		
42	45.0	46.0	1.00	2.0	0.0	39.0	5.8	2.3	473.	9999.		
43	45.0	46.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.		
44	44.0	46.0	1.00	0.713	3.740	39.0	5.8	2.3	473.	9999.		
45	43.0	46.0	1.00	0.0	0.140	39.0	5.8	2.3	473.	9999.		
46	42.0	46.0	1.00	11.250	14.700	39.0	5.8	2.3	473.	9999.		

TABLE 2.4(a) (Contd.)

	47	44.0	54.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	48	42.0	54.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	49	40.0	54.0	4.00	3.750	2.070	39.0	5.8	2.3	473.	9999.
	50	44.0	52.0	4.00	8.535	4.475	39.0	5.8	2.3	473.	9999.
	51	42.0	52.0	4.00	3.972	7.473	39.0	5.8	2.3	473.	9999.
	52	40.0	52.0	4.00	0.530	0.336	39.0	5.8	2.3	473.	9999.
	53	40.0	50.0	4.00	3.210	1.697	39.0	5.8	2.3	473.	9999.
	54	40.0	48.0	4.00	2.870	1.719	39.0	5.8	2.3	473.	9999.
	55	40.0	46.0	4.00	0.820	4.211	39.0	5.8	2.3	473.	9999.
	56	46.0	44.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	57	44.0	44.0	4.00	5.207	5.124	39.0	5.8	2.3	473.	9999.
	58	42.0	44.0	4.00	9.110	7.042	39.0	5.8	2.3	473.	9999.
	59	40.0	44.0	4.00	0.0	0.310	39.0	5.8	2.3	473.	9999.
	60	48.0	42.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	61	46.0	42.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	62	44.0	42.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	63	42.0	42.0	4.00	2.260	0.920	39.0	5.8	2.3	473.	9999.
	64	40.0	42.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	65	50.0	39.0	4.00	5.000	125.594	39.0	5.8	2.3	473.	9999.
	66	50.0	37.0	4.00	5.880	11.624	39.0	5.8	2.3	473.	9999.
	67	30.0	87.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	68	20.0	87.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	69	10.0	87.0	100.01	0.0	0.030	39.0	5.8	2.3	473.	9999.
	70	0.0	87.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	71	30.0	77.0	100.01	18.050	7.228	39.0	5.8	2.3	473.	9999.
Heavy Industry	72	20.0	77.0	100.01	0.0	0.070	39.0	5.8	2.3	473.	9999.
	73	10.0	77.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	74	0.0	77.0	100.01	1.370	0.970	39.0	5.8	2.3	473.	9999.
	75	30.0	67.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	76	20.0	67.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	77	10.0	67.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	78	0.0	67.0	100.01	0.0	0.090	39.0	5.8	2.3	473.	9999.
	79	40.0	61.0	25.00	0.180	0.010	39.0	5.8	2.3	473.	9999.
	80	35.0	62.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	81	30.0	62.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	82	20.0	57.0	100.01	0.140	0.010	39.0	5.8	2.3	473.	9999.
	83	10.0	57.0	100.01	1.930	1.748	39.0	5.8	2.3	473.	9999.
	84	0.0	57.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	85	40.0	56.0	25.00	0.0	0.411	39.0	5.8	2.3	473.	9999.
	86	35.0	57.0	25.00	0.990	0.155	39.0	5.8	2.3	473.	9999.
	87	30.0	57.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	88	35.0	52.0	25.00	10.000	11.227	39.0	5.8	2.3	473.	9999.
	89	30.0	52.0	25.00	0.059	0.976	39.0	5.8	2.3	473.	9999.
	90	20.0	47.0	100.01	1.450	0.020	39.0	5.8	2.3	473.	9999.
	91	10.0	47.0	100.01	0.490	0.240	39.0	5.8	2.3	473.	9999.
	92	0.0	47.0	100.01	1.350	0.870	39.0	5.8	2.3	473.	9999.
	93	35.0	47.0	25.00	3.920	1.817	39.0	5.8	2.3	473.	9999.
	94	30.0	47.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	95	35.0	42.0	25.00	86.730	43.800	39.0	5.8	2.3	473.	9999.
	96	30.0	42.0	25.00	2.440	54.881	39.0	5.8	2.3	473.	9999.
	97	20.0	37.0	100.01	5.920	0.340	39.0	5.8	2.3	473.	9999.
	98	10.0	37.0	100.01	0.960	0.730	39.0	5.8	2.3	473.	9999.

TABLE 2.4(a) (Contd.)

	99	0.0	37.0	100.01	0.250	0.300	39.0	5.8	2.3	473.	9999.
	100	45.0	37.0	25.00	10.249	63.906	39.0	5.8	2.3	473.	9999.
	101	40.0	37.0	25.00	1.073	0.609	39.0	5.8	2.3	473.	9999.
	102	35.0	37.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	103	30.0	37.0	25.00	0.660	0.120	39.0	5.8	2.3	473.	9999.
	104	45.0	32.0	25.00	19.550	57.540	39.0	5.8	2.3	473.	9999.
	105	40.0	32.0	25.00	39.160	3.192	39.0	5.8	2.3	473.	9999.
	106	30.0	27.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	107	20.0	27.0	100.01	34.180	10.450	39.0	5.8	2.3	473.	9999.
	108	10.0	27.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	109	45.0	27.0	25.00	0.215	5.327	39.0	5.8	2.3	473.	9999.
	110	40.0	27.0	25.00	0.160	0.010	39.0	5.8	2.3	473.	9999.
	111	45.0	22.0	25.00	5.367	9.300	39.0	5.8	2.3	473.	9999.
	112	40.0	22.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	113	30.0	17.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	114	20.0	17.0	100.01	5.160	0.300	39.0	5.8	2.3	473.	9999.
	115	10.0	17.0	100.01	77.460	86.180	39.0	5.8	2.3	473.	9999.
	116	45.0	17.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	117	40.0	17.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	118	40.0	7.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	119	30.0	7.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	120	20.0	7.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	121	10.0	7.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	122	52.0	36.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	123	53.0	35.0	1.00	168.220	12.493	39.0	5.8	2.3	473.	9999.
Heavy Industry	124	52.0	35.0	1.00	0.0	0.335	39.0	5.8	2.3	473.	9999.
	125	55.0	34.0	1.00	44.610	25.345	39.0	5.8	2.3	473.	9999.
	126	54.0	34.0	1.00	130.489	59.534	39.0	5.8	2.3	473.	9999.
	127	53.0	34.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	128	52.0	34.0	1.00	0.436	0.022	39.0	5.8	2.3	473.	9999.
	129	55.0	33.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	130	54.0	33.0	1.00	15.787	8.526	39.0	5.8	2.3	473.	9999.
	131	53.0	33.0	1.00	115.830	5.720	39.0	5.8	2.3	473.	9999.
	132	52.0	33.0	1.00	0.110	0.014	39.0	5.8	2.3	473.	9999.
	133	59.0	32.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	134	58.0	32.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	135	57.0	32.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	136	56.0	32.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	137	55.0	32.0	1.00	42.980	1.451	39.0	5.8	2.3	473.	9999.
	138	54.0	32.0	1.00	22.520	4.220	39.0	5.8	2.3	473.	9999.
	139	53.0	32.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	140	52.0	32.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	141	61.0	31.0	1.00	0.0	65.060	39.0	5.8	2.3	473.	9999.
	142	60.0	31.0	1.00	0.0	97.130	39.0	5.8	2.3	473.	9999.
	143	59.0	31.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	144	58.0	31.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	145	57.0	31.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	146	56.0	31.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	147	55.0	31.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	148	54.0	31.0	1.00	35.304	0.765	39.0	5.8	2.3	473.	9999.
	149	53.0	31.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	150	52.0	31.0	1.00	0.0	0.0	39.0	5.8	2.3	473.	9999.

TABLE 2.4(a) (Contd.)

	151	50.0	37.0	4.00	5.880	11.624	39.0	5.8	2.3	473.	9999.
	152	50.0	33.0	4.00	0.118	0.009	39.0	5.8	2.3	473.	9999.
	153	50.0	32.0	4.00	1.578	0.365	39.0	5.8	2.3	473.	9999.
	154	50.0	29.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	155	52.0	29.0	4.00	23.807	0.008	39.0	5.8	2.3	473.	9999.
	156	54.0	29.0	4.00	0.137	0.013	39.0	5.8	2.3	473.	9999.
	157	56.0	29.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	158	58.0	29.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	159	60.0	29.0	4.00	0.548	0.207	39.0	5.8	2.3	473.	9999.
	160	62.0	29.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	161	50.0	27.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	162	52.0	27.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	163	54.0	27.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	164	56.0	27.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	165	58.0	27.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	166	60.0	27.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
Heavy Industry	167	62.0	27.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	168	64.0	27.0	36.00	0.260	0.200	39.0	5.8	2.3	473.	9999.
	169	70.0	22.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	170	50.0	22.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	171	55.0	22.0	25.00	0.0	0.538	39.0	5.8	2.3	473.	9999.
	172	60.0	22.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	173	65.0	22.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	174	50.0	12.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	175	60.0	12.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	176	70.0	12.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	177	50.0	2.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	178	60.0	2.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	179	70.0	2.0	100.01	0.0	0.0	39.0	5.8	2.3	473.	9999.
	180	70.0	32.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	181	75.0	32.0	25.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	182	62.0	31.0	4.00	0.0	0.0	39.0	5.8	2.3	473.	9999.
	183	54.0	35.0	1.00	3.617	2.902	39.0	5.8	2.3	473.	9999.
	184	56.0	33.0	1.00	60.610	152.200	39.0	5.8	2.3	473.	9999.
	185	46.0	51.0	1.00	4.380	1.710	39.0	0.0	0.0	0.	9999.
	186	45.0	51.0	1.00	6.680	2.920	39.0	0.0	0.0	0.	9999.
	187	44.0	51.0	1.00	3.661	1.791	39.0	0.0	0.0	0.	9999.
	188	43.0	51.0	1.00	3.850	2.390	39.0	0.0	0.0	0.	9999.
	189	42.0	51.0	1.00	2.770	1.480	39.0	0.0	0.0	0.	9999.
	190	46.0	50.0	1.00	8.419	3.119	39.0	0.0	0.0	0.	9999.
	191	45.0	50.0	1.00	6.489	2.793	39.0	0.0	0.0	0.	9999.
	192	44.0	50.0	1.00	4.460	2.280	39.0	0.0	0.0	0.	9999.
Light Industry	193	43.0	50.0	1.00	4.769	2.362	39.0	0.0	0.0	0.	9999.
	194	42.0	50.0	1.00	3.703	1.872	39.0	0.0	0.0	0.	9999.
	195	46.0	49.0	1.00	3.415	1.332	39.0	0.0	0.0	0.	9999.
	196	45.0	49.0	1.00	12.213	4.134	39.0	0.0	0.0	0.	9999.
	197	44.0	49.0	1.00	11.730	3.983	39.0	0.0	0.0	0.	9999.
	198	43.0	49.0	1.00	3.870	1.590	39.0	0.0	0.0	0.	9999.
	199	42.0	49.0	1.00	3.901	2.039	39.0	0.0	0.0	0.	9999.
	200	46.1	48.0	1.00	3.230	1.180	39.0	0.0	0.0	0.	9999.
	201	45.0	48.0	1.00	2.454	1.043	39.0	0.0	0.0	0.	9999.
	202	44.0	48.0	1.00	4.792	1.952	39.0	0.0	0.0	0.	9999.

TABLE 2.4(a) (Contd.)

	203	43.0	48.0	1.00	2.710	1.120	39.0	0.0	0.0	0.0	9999.
	204	42.0	48.0	1.00	3.268	1.631	39.0	0.0	0.0	0.0	9999.
	205	46.0	47.0	1.00	3.015	1.288	39.0	0.0	0.0	0.0	9999.
	206	45.0	47.0	1.00	4.001	1.907	39.0	0.0	0.0	0.0	9999.
	207	44.0	47.0	1.00	1.480	0.520	39.0	0.0	0.0	0.0	9999.
	208	43.0	47.0	1.00	1.413	1.646	39.0	0.0	0.0	0.0	9999.
	209	42.0	47.0	1.00	2.635	1.660	39.0	0.0	0.0	0.0	9999.
	210	47.0	46.0	1.00	0.920	0.420	39.0	0.0	0.0	0.0	9999.
	211	46.0	46.0	1.00	3.950	1.990	39.0	0.0	0.0	0.0	9999.
	212	45.0	46.0	1.00	3.905	1.154	39.0	0.0	0.0	0.0	9999.
	213	44.0	46.0	1.00	4.561	3.047	39.0	0.0	0.0	0.0	9999.
	214	43.0	46.0	1.00	1.160	0.480	39.0	0.0	0.0	0.0	9999.
	215	42.0	46.0	1.00	1.730	0.660	39.0	0.0	0.0	0.0	9999.
	216	44.0	54.0	4.00	18.050	9.350	39.0	0.0	0.0	0.0	9999.
	217	42.0	54.0	4.00	10.080	5.130	39.0	0.0	0.0	0.0	9999.
	218	40.0	54.0	4.00	7.980	4.170	39.0	0.0	0.0	0.0	9999.
	219	44.0	52.0	4.00	17.964	13.174	39.0	0.0	0.0	0.0	9999.
	220	42.0	52.0	4.00	12.037	6.812	39.0	0.0	0.0	0.0	9999.
	221	40.0	52.0	4.00	10.963	5.770	39.0	0.0	0.0	0.0	9999.
	222	40.0	50.0	4.00	8.786	5.781	39.0	0.0	0.0	0.0	9999.
	223	40.0	48.0	4.00	15.315	12.800	39.0	0.0	0.0	0.0	9999.
	224	40.0	46.0	4.00	4.648	2.188	39.0	0.0	0.0	0.0	9999.
	225	46.0	44.0	4.00	18.520	10.820	39.0	0.0	0.0	0.0	9999.
	226	44.0	44.0	4.00	8.861	3.636	39.0	0.0	0.0	0.0	9999.
	227	42.0	44.0	4.00	7.962	3.108	39.0	0.0	0.0	0.0	9999.
Light Industry	228	40.0	44.0	4.00	5.234	2.153	39.0	0.0	0.0	0.0	9999.
	229	48.0	42.0	4.00	7.220	1.980	39.0	0.0	0.0	0.0	9999.
	230	46.0	42.0	4.00	20.820	11.578	39.0	0.0	0.0	0.0	9999.
	231	44.0	42.0	4.00	9.462	4.563	39.0	0.0	0.0	0.0	9999.
	232	42.0	42.0	4.00	4.580	2.380	39.0	0.0	0.0	0.0	9999.
	233	40.0	42.0	4.00	2.280	0.950	39.0	0.0	0.0	0.0	9999.
	234	50.0	39.0	4.00	0.580	2.560	39.0	0.0	0.0	0.0	9999.
	235	50.0	37.0	4.00	1.510	0.810	39.0	0.0	0.0	0.0	9999.
	236	30.0	87.0	100.01	1.040	1.000	39.0	0.0	0.0	0.0	9999.
	237	20.0	87.0	100.01	1.040	1.000	39.0	0.0	0.0	0.0	9999.
	238	10.0	87.0	100.01	0.270	0.290	39.0	0.0	0.0	0.0	9999.
	239	0.0	87.0	100.01	0.270	0.290	39.0	0.0	0.0	0.0	9999.
	240	30.0	77.0	100.01	19.339	13.820	39.0	0.0	0.0	0.0	9999.
	241	20.0	77.0	100.01	1.040	1.000	39.0	0.0	0.0	0.0	9999.
	242	10.0	77.0	100.01	0.270	0.290	39.0	0.0	0.0	0.0	9999.
	243	0.0	77.0	100.01	0.340	0.360	39.0	0.0	0.0	0.0	9999.
	244	30.0	67.0	100.01	3.513	1.407	39.0	0.0	0.0	0.0	9999.
	245	20.0	67.0	100.01	1.040	1.000	39.0	0.0	0.0	0.0	9999.
	246	10.0	67.0	100.01	0.270	0.290	39.0	0.0	0.0	0.0	9999.
	247	0.0	67.0	100.01	0.270	0.290	39.0	0.0	0.0	0.0	9999.
	248	40.0	61.0	25.00	7.520	2.400	39.0	0.0	0.0	0.0	9999.
	249	35.0	62.0	25.00	5.640	1.800	39.0	0.0	0.0	0.0	9999.
	250	30.0	62.0	25.00	5.640	1.800	39.0	0.0	0.0	0.0	9999.
	251	20.0	57.0	100.01	1.880	0.600	39.0	0.0	0.0	0.0	9999.
	252	10.0	57.0	100.01	6.440	2.160	39.0	0.0	0.0	0.0	9999.
	253	0.0	57.0	100.01	1.120	2.000	39.0	0.0	0.0	0.0	9999.
	254	40.0	56.0	25.00	27.390	18.640	39.0	0.0	0.0	0.0	9999.

TABLE 2.4(a) (Contd.)

	255	35.0	57.0	25.00	10.900	3.810	39.0	0.0	0.0	0.0	9999.
	256	30.0	57.0	25.00	20.075	28.428	39.0	0.0	0.0	0.0	9999.
	257	35.0	52.0	25.00	15.558	6.617	39.0	0.0	0.0	0.0	9999.
	258	30.0	52.0	25.00	19.170	6.310	39.0	0.0	0.0	0.0	9999.
	259	20.0	47.0	100.01	1.720	2.550	39.0	0.0	0.0	0.0	9999.
	260	10.0	47.0	100.01	0.0	1.860	39.0	0.0	0.0	0.0	9999.
	261	0.0	47.0	100.01	0.480	0.850	39.0	0.0	0.0	0.0	9999.
	262	35.0	47.0	25.00	15.820	6.976	39.0	0.0	0.0	0.0	9999.
	263	30.0	47.0	25.00	9.400	3.920	39.0	0.0	0.0	0.0	9999.
	264	35.0	42.0	25.00	16.870	4.785	39.0	0.0	0.0	0.0	9999.
	265	30.0	42.0	25.00	12.700	4.000	39.0	0.0	0.0	0.0	9999.
	266	20.0	37.0	100.01	2.910	2.550	39.0	0.0	0.0	0.0	9999.
	267	10.0	37.0	100.01	1.240	1.000	39.0	0.0	0.0	0.0	9999.
	268	0.0	37.0	100.01	1.120	2.000	39.0	0.0	0.0	0.0	9999.
	269	45.0	37.0	25.00	27.477	14.784	39.0	0.0	0.0	0.0	9999.
	270	40.0	37.0	25.00	12.190	6.290	39.0	0.0	0.0	0.0	9999.
	271	35.0	37.0	25.00	9.400	3.000	39.0	0.0	0.0	0.0	9999.
	272	30.0	37.0	25.00	9.400	3.000	39.0	0.0	0.0	0.0	9999.
	273	45.0	32.0	25.00	4.920	2.194	39.0	0.0	0.0	0.0	9999.
	274	40.0	32.0	25.00	2.613	0.936	39.0	0.0	0.0	0.0	9999.
	275	30.0	27.0	100.01	1.880	0.600	39.0	0.0	0.0	0.0	9999.
	276	20.0	27.0	100.01	0.240	1.050	39.0	0.0	0.0	0.0	9999.
	277	10.0	27.0	100.01	0.130	0.200	39.0	0.0	0.0	0.0	9999.
	278	45.0	27.0	25.00	9.400	3.000	39.0	0.0	0.0	0.0	9999.
	279	40.0	27.0	25.00	9.400	3.000	39.0	0.0	0.0	0.0	9999.
Light Industry	280	45.0	22.0	25.00	9.400	3.190	39.0	0.0	0.0	0.0	9999.
	281	40.0	22.0	25.00	37.600	12.000	39.0	0.0	0.0	0.0	9999.
	282	30.0	17.0	100.01	0.140	0.210	39.0	0.0	0.0	0.0	9999.
	283	20.0	17.0	100.01	3.690	2.110	39.0	0.0	0.0	0.0	9999.
	284	10.0	17.0	100.01	0.270	0.410	39.0	0.0	0.0	0.0	9999.
	285	45.0	17.0	25.00	0.270	0.410	39.0	0.0	0.0	0.0	9999.
	286	40.0	17.0	25.00	0.270	0.410	39.0	0.0	0.0	0.0	9999.
	287	40.0	7.0	100.01	0.130	0.200	39.0	0.0	0.0	0.0	9999.
	288	30.0	7.0	100.01	0.140	0.210	39.0	0.0	0.0	0.0	9999.
	289	20.0	7.0	100.01	0.130	0.200	39.0	0.0	0.0	0.0	9999.
	290	10.0	7.0	100.01	0.820	0.840	39.0	0.0	0.0	0.0	9999.
	291	52.0	36.0	1.00	1.670	0.890	39.0	0.0	0.0	0.0	9999.
	292	53.0	35.0	1.00	0.950	0.540	39.0	0.0	0.0	0.0	9999.
	293	52.0	35.0	1.00	1.770	0.970	39.0	0.0	0.0	0.0	9999.
	294	55.0	34.0	1.00	0.910	0.500	39.0	0.0	0.0	0.0	9999.
	295	54.0	34.0	1.00	0.680	0.410	39.0	0.0	0.0	0.0	9999.
	296	53.0	34.0	1.00	0.570	0.330	39.0	0.0	0.0	0.0	9999.
	297	52.0	34.0	1.00	0.520	0.280	39.0	0.0	0.0	0.0	9999.
	298	55.0	33.0	1.00	1.930	1.040	39.0	0.0	0.0	0.0	9999.
	299	54.0	33.0	1.00	2.090	1.160	39.0	0.0	0.0	0.0	9999.
	300	53.0	33.0	1.00	0.810	0.450	39.0	0.0	0.0	0.0	9999.
	301	52.0	33.0	1.00	0.510	0.290	39.0	0.0	0.0	0.0	9999.
	302	59.0	32.0	1.00	0.500	0.340	39.0	0.0	0.0	0.0	9999.
	303	58.0	32.0	1.00	0.510	0.290	39.0	0.0	0.0	0.0	9999.
	304	57.0	32.0	1.00	0.080	0.050	39.0	0.0	0.0	0.0	9999.
	305	56.0	32.0	1.00	0.520	0.300	39.0	0.0	0.0	0.0	9999.
	306	55.0	32.0	1.00	0.960	0.550	39.0	0.0	0.0	0.0	9999.

TABLE 2.4(a) (Contd.)

Light Industry	307	54.0	32.0	1.00	1.430	0.800	39.0	0.0	0.0	0.	9999.
	308	53.0	32.0	1.00	2.370	1.300	39.0	0.0	0.0	0.	9999.
	309	52.0	32.0	1.00	1.840	1.010	39.0	0.0	0.0	0.	9999.
	310	61.0	31.0	1.00	0.510	0.290	39.0	0.0	0.0	0.	9999.
	311	60.0	31.0	1.00	0.510	0.290	39.0	0.0	0.0	0.	9999.
	312	59.0	31.0	1.00	0.640	0.370	39.0	0.0	0.0	0.	9999.
	313	58.0	31.0	1.00	0.630	0.410	39.0	0.0	0.0	0.	9999.
	314	57.0	31.0	1.00	0.520	0.340	39.0	0.0	0.0	0.	9999.
	315	56.0	31.0	1.00	0.960	0.550	39.0	0.0	0.0	0.	9999.
	316	55.0	31.0	1.00	4.520	2.560	39.0	0.0	0.0	0.	9999.
	317	54.0	31.0	1.00	0.960	0.600	39.0	0.0	0.0	0.	9999.
	318	53.0	31.0	1.00	0.940	0.530	39.0	0.0	0.0	0.	9999.
	319	52.0	31.0	1.00	1.510	0.810	39.0	0.0	0.0	0.	9999.
	320	50.0	37.0	4.00	1.510	0.810	39.0	0.0	0.0	0.	9999.
	321	50.0	33.0	4.00	1.740	0.950	39.0	0.0	0.0	0.	9999.
	322	50.0	32.0	4.00	1.920	1.045	39.0	0.0	0.0	0.	9999.
	323	50.0	29.0	4.00	1.920	1.040	39.0	0.0	0.0	0.	9999.
	324	52.0	29.0	4.00	4.850	2.710	39.0	0.0	0.0	0.	9999.
	325	54.0	29.0	4.00	4.170	2.260	39.0	0.0	0.0	0.	9999.
	326	56.0	29.0	4.00	3.110	1.700	39.0	0.0	0.0	0.	9999.
	327	58.0	29.0	4.00	8.120	4.390	39.0	0.0	0.0	0.	9999.
	328	60.0	29.0	4.00	7.560	4.110	39.0	0.0	0.0	0.	9999.
	329	62.0	29.0	4.00	1.190	0.670	39.0	0.0	0.0	0.	9999.
	330	50.0	27.0	4.00	0.720	0.390	39.0	0.0	0.0	0.	9999.
	331	52.0	27.0	4.00	2.290	1.250	39.0	0.0	0.0	0.	9999.
	332	54.0	27.0	4.00	3.390	1.850	39.0	0.0	0.0	0.	9999.
	333	56.0	27.0	4.00	0.710	0.410	39.0	0.0	0.0	0.	9999.
	334	58.0	27.0	4.00	1.410	0.780	39.0	0.0	0.0	0.	9999.
	335	60.0	27.0	4.00	2.050	1.110	39.0	0.0	0.0	0.	9999.
	336	62.0	27.0	4.00	1.230	0.690	39.0	0.0	0.0	0.	9999.
	337	64.0	27.0	36.00	4.670	2.660	39.0	0.0	0.0	0.	9999.
	338	70.0	22.0	100.01	3.620	1.850	39.0	0.0	0.0	0.	9999.
	339	50.0	22.0	25.00	3.310	1.900	39.0	0.0	0.0	0.	9999.
	340	55.0	22.0	25.00	4.670	2.580	39.0	0.0	0.0	0.	9999.
	341	60.0	22.0	25.00	7.760	4.240	39.0	0.0	0.0	0.	9999.
	342	65.0	22.0	25.00	1.500	0.810	39.0	0.0	0.0	0.	9999.
	343	50.0	12.0	100.01	4.610	2.600	39.0	0.0	0.0	0.	9999.
	344	60.0	12.0	100.01	1.160	0.700	39.0	0.0	0.0	0.	9999.
	345	70.0	12.0	100.01	4.620	1.936	39.0	0.0	0.0	0.	9999.
	346	50.0	2.0	100.01	1.170	0.730	39.0	0.0	0.0	0.	9999.
	347	60.0	2.0	100.01	0.390	0.200	39.0	0.0	0.0	0.	9999.
	348	70.0	2.0	100.01	0.830	0.450	39.0	0.0	0.0	0.	9999.
	349	70.0	32.0	25.00	0.250	0.130	39.0	0.0	0.0	0.	9999.
	350	75.0	32.0	25.00	0.490	0.270	39.0	0.0	0.0	0.	9999.
	351	62.0	31.0	4.00	0.450	0.260	39.0	0.0	0.0	0.	9999.
	352	54.0	35.0	1.00	0.450	0.250	39.0	0.0	0.0	0.	9999.
	353	55.0	33.0	1.00	0.900	0.510	39.0	0.0	0.0	0.	9999.
TOTAL					0.47288E 04	0.15632E 04					
AREA SOURCE TOTAL					0.18870E 04	0.14413E 04					
POINT SOURCE TOTAL					0.28420E 04	0.12191E 03					

TABLE 2.4(b). Illinois-Chicago Region--1980 Emissions by Area

SOURCE DATA												
	SOURCE NUMBER	SOURCE LOCATION (MILES)		SOURCE AREA SQUARE MILES	ANNUAL SOURCE EMISSION RATE (TONS/DAY)		STACK DATA				SOURCE CLASS	
		HORIZONTAL	VERTICAL		SO2	PART	HT (M)	DIAM (M)	VEL (M/SEC)	TEMP NO DEG.K		
Power Plants	1	20.4	23.9	0.0	262.395	1.989	137.3	4.1	40.5	464.	4911.	
	2	20.4	23.9	0.0	136.935	59.670	75.6	3.5	13.4	464.	4911.	
	3	19.9	23.9	0.0	872.098	28.305	168.0	5.3	36.6	464.	4911.	
	4	37.8	45.1	0.0	128.520	2.876	65.0	3.0	36.6	464.	4911.	
	5	37.6	84.7	0.0	394.740	25.903	125.0	4.3	29.6	464.	4911.	
	6	23.3	33.4	0.0	229.515	9.868	106.5	4.0	18.3	464.	4911.	
	7	23.3	33.5	0.0	484.244	18.850	145.6	4.7	27.5	464.	4911.	
	8	51.0	38.2	0.0	573.749	1.744	116.0	7.3	5.5	464.	4911.	
	9	71.5	33.4	0.0	43.605	0.181	122.0	4.6	45.1	430.	4911.	
	10	57.0	33.3	0.0	408.510	8.262	72.0	6.0	24.9	416.	4911.	
	11	42.5	54.2	0.0	0.0	0.0	100.0	4.3	6.5	464.	4911.	
	12	44.6	48.1	0.0	137.394	2.749	96.0	5.1	13.2	464.	4911.	
	13	44.6	48.1	0.0	178.551	5.955	147.5	6.0	13.0	464.	4911.	
	14	41.1	46.5	0.0	464.047	17.151	124.7	3.4	42.7	464.	4911.	
	15	50.0	38.4	0.0	33.997	3.017	100.0	2.6	12.9	464.	4911.	
	16	46.0	51.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	17	45.0	51.0	1.00	0.155	0.640	41.0	2.0	1.7	492.	9999.	
	18	44.0	51.0	1.00	1.708	4.642	36.0	1.7	1.5	412.	9999.	
	19	43.0	51.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	20	42.0	51.0	1.00	0.0	0.462	55.0	2.6	0.7	492.	9999.	
	21	46.0	50.0	1.00	0.0	4.190	38.4	2.0	2.2	592.	9999.	
	22	45.0	50.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	23	44.0	50.0	1.00	0.0	1.216	35.0	3.0	4.5	287.	9999.	
	24	43.0	50.0	1.00	0.0	0.855	7.0	0.7	10.0	285.	9999.	
	25	42.0	50.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	26	46.0	49.0	1.00	0.0	0.018	105.0	1.5	1.0	533.	9999.	
	27	45.0	49.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	28	44.0	49.0	1.00	0.0	0.333	14.6	0.4	8.0	300.	9999.	
	29	43.0	49.0	1.00	0.0	0.290	7.0	0.7	10.0	285.	9999.	
	30	42.0	49.0	1.00	0.0	0.344	18.0	1.8	8.0	920.	9999.	
Heavy Industry	31	46.1	48.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	32	45.0	48.0	1.00	0.311	3.370	76.0	3.6	0.8	464.	9999.	
	33	44.0	48.0	1.00	0.0	2.485	13.7	1.8	7.5	920.	9999.	
	34	43.0	48.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	35	42.0	48.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	36	46.0	47.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	37	45.0	47.0	1.00	0.155	0.265	31.3	1.5	1.4	432.	9999.	
	38	44.0	47.0	1.00	1.242	0.0	0.0	0.0	0.0	0.	9999.	
	39	43.0	47.0	1.00	2.174	1.533	38.8	2.6	7.0	408.	9999.	
	40	42.0	47.0	1.00	0.932	7.996	41.3	1.7	4.7	406.	9999.	
	41	47.0	46.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	42	46.0	46.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	43	45.0	46.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.	
	44	44.0	46.0	1.00	1.642	3.740	82.0	4.9	10.3	533.	9999.	
	45	43.0	46.0	1.00	0.155	0.196	12.2	1.6	7.2	533.	9999.	
	46	42.0	46.0	1.00	0.932	25.431	65.8	2.4	5.3	415.	9999.	

TABLE 2.4(b) (Contd.)

	47	44.0	54.0	4.00	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	48	42.0	54.0	4.00	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	49	40.0	54.0	4.00	0.0	2.231	65.7	2.8	1.1	478.	9999.
	50	44.0	52.0	4.00	1.087	7.447	25.9	1.3	8.0	570.	9999.
	51	42.0	52.0	4.00	1.567	10.893	37.3	1.9	4.9	544.	9999.
	52	40.0	52.0	4.00	0.0	0.481	34.6	1.6	3.7	407.	9999.
	53	40.0	50.0	4.00	0.0	2.766	37.0	2.1	5.5	552.	9999.
	54	40.0	48.0	4.00	0.155	1.724	50.1	2.6	4.2	433.	9999.
	55	40.0	46.0	4.00	2.951	6.991	39.7	2.2	6.8	498.	9999.
	56	46.0	44.0	4.00	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	57	44.0	44.0	4.00	2.951	6.673	45.1	2.1	10.4	469.	9999.
	58	42.0	44.0	4.00	1.087	8.929	58.9	2.8	1.4	464.	9999.
	59	40.0	44.0	4.00	2.330	0.446	20.0	0.8	12.0	394.	9999.
	60	48.0	42.0	4.00	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	61	46.0	42.0	4.00	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	62	44.0	42.0	4.00	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	63	42.0	42.0	4.00	0.0	1.325	63.0	3.0	1.2	464.	9999.
	64	40.0	42.0	4.00	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	65	50.0	39.0	4.00	4.349	175.801	45.2	3.3	12.3	513.	9999.
	66	50.0	37.0	4.00	0.932	16.812	28.6	2.7	3.2	418.	9999.
	67	30.0	87.0	100.01	1.621	0.0	0.0	0.0	0.0	0.0	9999.
	68	20.0	87.0	100.01	0.360	0.0	0.0	0.0	0.0	0.0	9999.
	69	10.0	87.0	100.01	0.181	0.042	12.2	0.9	10.0	1033.	9999.
	70	0.0	87.0	100.01	0.466	0.0	0.0	0.0	0.0	0.0	9999.
	71	30.0	77.0	100.01	19.035	11.407	30.3	2.1	5.8	427.	9999.
	72	20.0	77.0	100.01	0.0	0.121	9.1	2.2	6.3	390.	9999.
	73	10.0	77.0	100.01	0.036	0.0	0.0	0.0	0.0	0.0	9999.
	74	0.0	77.0	100.01	0.109	1.678	62.3	1.8	7.3	464.	9999.
	75	30.0	67.0	100.01	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	76	20.0	67.0	100.01	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	77	10.0	67.0	100.01	1.288	0.0	0.0	0.0	0.0	0.0	9999.
	78	0.0	67.0	100.01	0.127	0.126	9.1	1.2	2.0	523.	9999.
	79	40.0	61.0	25.00	0.0	0.017	9.1	1.1	2.4	492.	9999.
	80	35.0	62.0	25.00	0.0	0.0	0.0	0.0	0.0	0.0	9999.
	81	30.0	62.0	25.00	0.155	0.0	0.0	0.0	0.0	0.0	9999.
	82	20.0	57.0	100.01	1.398	0.016	9.1	1.5	10.6	492.	9999.
	83	10.0	57.0	100.01	10.406	2.371	24.5	1.8	7.6	428.	9999.
	84	0.0	57.0	100.01	0.160	0.0	0.0	0.0	0.0	0.0	9999.
	85	40.0	56.0	25.00	0.0	0.711	12.8	2.1	6.3	437.	9999.
	86	35.0	57.0	25.00	0.0	0.232	15.0	3.3	4.3	450.	9999.
	87	30.0	57.0	25.00	0.311	0.0	0.0	0.0	0.0	0.0	9999.
	88	35.0	52.0	25.00	0.0	14.794	44.4	1.4	5.6	375.	9999.
	89	30.0	52.0	25.00	5.591	1.388	24.4	2.6	4.7	457.	9999.
	90	20.0	47.0	100.01	0.062	0.026	48.8	1.8	4.3	464.	9999.
	91	10.0	47.0	100.01	0.109	0.404	34.6	1.3	3.0	478.	9999.
	92	0.0	47.0	100.01	1.116	1.234	23.9	1.0	12.0	493.	9999.
	93	35.0	47.0	25.00	0.0	1.830	47.6	2.8	1.9	464.	9999.
	94	30.0	47.0	25.00	3.727	0.0	0.0	0.0	0.0	0.0	9999.
	95	35.0	42.0	25.00	22.831	46.396	36.8	1.9	5.2	472.	9999.
	96	30.0	42.0	25.00	6.368	77.621	16.0	8.0	4.4	492.	9999.
	97	20.0	37.0	100.01	0.403	0.588	46.4	3.9	1.7	464.	9999.
	98	10.0	37.0	100.01	0.977	1.085	29.1	1.6	5.6	572.	9999.

Heavy
Industry

TABLE 2.4(b) (Contd.)

	99	0.0	37.0	100.01	4.042	0.508	25.1	1.5	5.3	515.	9999.
	100	45.0	37.0	25.00	13.100	87.684	46.7	3.4	8.5	440.	9999.
	101	40.0	37.0	25.00	0.0	1.059	31.3	1.6	5.4	425.	9999.
	102	35.0	37.0	25.00	5.902	0.0	0.0	0.0	0.0	0.	9999.
	103	30.0	37.0	25.00	1.398	0.208	28.1	3.7	1.3	464.	9999.
	104	45.0	32.0	25.00	29.664	83.081	35.7	3.2	6.4	431.	9999.
	105	40.0	32.0	25.00	17.262	5.142	28.0	1.8	6.5	474.	9999.
	106	30.0	27.0	100.01	5.902	0.0	0.0	0.0	0.0	0.	9999.
	107	20.0	27.0	100.01	13.368	16.310	32.7	2.7	3.9	416.	9999.
	108	10.0	27.0	100.01	8.594	0.0	0.0	0.0	0.0	0.	9999.
	109	45.0	27.0	25.00	0.721	7.611	15.6	2.9	3.2	526.	9999.
	110	40.0	27.0	25.00	0.0	0.016	33.5	2.2	1.2	492.	9999.
	111	45.0	22.0	25.00	10.250	13.715	24.2	2.1	7.5	588.	9999.
	112	40.0	22.0	25.00	1.708	0.0	0.0	0.0	0.0	0.	9999.
	113	30.0	17.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	114	20.0	17.0	100.01	8.019	0.519	25.9	1.0	8.1	429.	9999.
	115	10.0	17.0	100.01	68.842	120.383	19.9	1.5	5.1	412.	9999.
	116	45.0	17.0	25.00	0.955	0.0	0.0	0.0	0.0	0.	9999.
	117	40.0	17.0	25.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	118	40.0	7.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	119	30.0	7.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	120	20.0	7.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	121	10.0	7.0	100.01	2.864	0.0	0.0	0.0	0.0	0.	9999.
	122	52.0	36.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	123	53.0	35.0	1.00	274.416	20.886	47.4	2.4	6.8	558.	9999.
Heavy Industry	124	52.0	35.0	1.00	0.0	0.482	91.4	2.7	6.5	505.	9999.
	125	55.0	34.0	1.00	62.454	35.482	41.1	2.8	6.7	476.	9999.
	126	54.0	34.0	1.00	182.684	83.347	48.8	3.0	9.5	448.	9999.
	127	53.0	34.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	128	52.0	34.0	1.00	0.754	0.038	27.3	2.0	4.1	464.	9999.
	129	55.0	33.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	130	54.0	33.0	1.00	27.092	14.053	31.0	1.7	3.9	446.	9999.
	131	53.0	33.0	1.00	187.644	9.266	39.6	1.8	3.3	726.	9999.
	132	52.0	33.0	1.00	0.178	0.022	12.2	1.5	3.6	492.	9999.
	133	59.0	32.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	134	58.0	32.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	135	57.0	32.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	136	56.0	32.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	137	55.0	32.0	1.00	69.627	2.351	38.1	1.5	4.0	429.	9999.
	138	54.0	32.0	1.00	38.734	6.973	24.6	1.7	14.5	495.	9999.
	139	53.0	32.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	140	52.0	32.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	141	61.0	31.0	1.00	0.0	91.084	23.8	2.6	8.3	358.	9999.
	142	60.0	31.0	1.00	0.0	135.982	43.1	3.7	6.4	528.	9999.
	143	59.0	31.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	144	58.0	31.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	145	57.0	31.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	146	56.0	31.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	147	55.0	31.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	148	54.0	31.0	1.00	60.625	1.071	36.1	1.4	12.6	429.	9999.
	149	53.0	31.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	150	52.0	31.0	1.00	0.0	0.0	0.0	0.0	0.0	0.	9999.

TABLE 2.4(b) (Contd.)

	151	50.0	37.0	4.00	1.398	16.812	28.6	2.7	3.2	418.	9999.
	152	50.0	33.0	4.00	0.466	0.012	33.6	1.4	1.7	533.	9999.
	153	50.0	32.0	4.00	0.466	0.511	25.8	1.3	4.2	513.	9999.
	154	50.0	29.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	155	52.0	29.0	4.00	40.948	0.014	49.5	1.4	4.7	413.	9999.
	156	54.0	29.0	4.00	0.177	0.017	25.0	1.8	3.4	464.	9999.
	157	56.0	29.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	158	58.0	29.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	159	60.0	29.0	4.00	0.789	0.298	21.0	1.1	5.5	492.	9999.
	160	62.0	29.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	161	50.0	27.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	162	52.0	27.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	163	54.0	27.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	164	56.0	27.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	165	58.0	27.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	166	60.0	27.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
Heavy Industry	167	62.0	27.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	168	64.0	27.0	36.00	1.344	0.280	32.0	1.0	10.0	464.	9999.
	169	70.0	22.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	170	50.0	22.0	25.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	171	55.0	22.0	25.00	0.0	0.753	18.3	2.3	1.1	1030.	9999.
	172	60.0	22.0	25.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	173	65.0	22.0	25.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	174	50.0	12.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	175	60.0	12.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	176	70.0	12.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	177	50.0	2.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	178	60.0	2.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	179	70.0	2.0	100.01	0.0	0.0	0.0	0.0	0.0	0.	9999.
	180	70.0	32.0	25.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	181	75.0	32.0	25.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	182	62.0	31.0	4.00	0.0	0.0	0.0	0.0	0.0	0.	9999.
	183	54.0	35.0	1.00	5.064	4.063	50.0	2.0	9.8	453.	9999.
	184	56.0	33.0	1.00	88.490	222.212	65.0	4.5	14.0	475.	9999.
	185	46.0	51.0	1.00	2.520	1.710	39.0	0.0	0.0	0.	9999.
	186	45.0	51.0	1.00	4.621	2.920	39.0	0.0	0.0	0.	9999.
	187	44.0	51.0	1.00	4.534	1.791	39.0	0.0	0.0	0.	9999.
	188	43.0	51.0	1.00	1.580	2.390	39.0	0.0	0.0	0.	9999.
	189	42.0	51.0	1.00	1.650	1.480	39.0	0.0	0.0	0.	9999.
	190	46.0	50.0	1.00	13.230	3.119	39.0	0.0	0.0	0.	9999.
	191	45.0	50.0	1.00	7.073	2.793	39.0	0.0	0.0	0.	9999.
Light Industry	192	44.0	50.0	1.00	5.074	5.280	39.0	0.0	0.0	0.	9999.
	193	43.0	50.0	1.00	4.133	2.362	39.0	0.0	0.0	0.	9999.
	194	42.0	50.0	1.00	5.965	1.872	39.0	0.0	0.0	0.	9999.
	195	46.0	49.0	1.00	10.290	1.332	39.0	0.0	0.0	0.	9999.
	196	45.0	49.0	1.00	5.132	4.134	39.0	0.0	0.0	0.	9999.
	197	44.0	49.0	1.00	11.823	3.983	39.0	0.0	0.0	0.	9999.
	198	43.0	49.0	1.00	2.500	1.590	39.0	0.0	0.0	0.	9999.
	199	42.0	49.0	1.00	3.171	2.039	39.0	0.0	0.0	0.	9999.
	200	46.1	48.0	1.00	1.930	1.180	39.0	0.0	0.0	0.	9999.
	201	45.0	48.0	1.00	5.917	1.043	39.0	0.0	0.0	0.	9999.
	202	44.0	48.0	1.00	3.252	1.952	39.0	0.0	0.0	0.	9999.

TABLE 2.4(b) (Contd.)

	203	43.0	48.0	1.00	2.302	1.120	39.0	0.0	0.0	0.	9999.
	204	42.0	48.0	1.00	3.883	1.631	39.0	0.0	0.0	0.	9999.
	205	46.0	47.0	1.00	2.892	1.288	39.0	0.0	0.0	0.	9999.
	206	45.0	47.0	1.00	4.493	1.907	39.0	0.0	0.0	0.	9999.
	207	44.0	47.0	1.00	4.655	0.520	39.0	0.0	0.0	0.	9999.
	208	43.0	47.0	1.00	4.635	1.646	39.0	0.0	0.0	0.	9999.
	209	42.0	47.0	1.00	5.175	1.660	39.0	0.0	0.0	0.	9999.
	210	47.0	46.0	1.00	1.820	0.420	39.0	0.0	0.0	0.	9999.
	211	46.0	46.0	1.00	2.430	1.990	39.0	0.0	0.0	0.	9999.
	212	45.0	46.0	1.00	10.062	1.154	39.0	0.0	0.0	0.	9999.
	213	44.0	46.0	1.00	5.855	3.047	39.0	0.0	0.0	0.	9999.
	214	43.0	46.0	1.00	1.551	0.480	39.0	0.0	0.0	0.	9999.
	215	42.0	46.0	1.00	3.974	0.660	39.0	0.0	0.0	0.	9999.
	216	44.0	54.0	4.00	16.830	9.350	39.0	0.0	0.0	0.	9999.
	217	42.0	54.0	4.00	12.265	5.130	39.0	0.0	0.0	0.	9999.
	218	40.0	54.0	4.00	9.114	4.170	39.0	0.0	0.0	0.	9999.
	219	44.0	52.0	4.00	14.595	13.174	39.0	0.0	0.0	0.	9999.
	220	42.0	52.0	4.00	12.199	6.812	39.0	0.0	0.0	0.	9999.
	221	40.0	52.0	4.00	11.107	5.770	39.0	0.0	0.0	0.	9999.
	222	40.0	50.0	4.00	13.810	5.781	39.0	0.0	0.0	0.	9999.
	223	40.0	48.0	4.00	17.257	12.800	39.0	0.0	0.0	0.	9999.
	224	40.0	46.0	4.00	10.812	2.188	39.0	0.0	0.0	0.	9999.
	225	46.0	44.0	4.00	20.931	10.820	39.0	0.0	0.0	0.	9999.
	226	44.0	44.0	4.00	17.335	3.636	39.0	0.0	0.0	0.	9999.
	227	42.0	44.0	4.00	9.990	3.108	39.0	0.0	0.0	0.	9999.
Light Industry	228	40.0	44.0	4.00	15.327	2.153	39.0	0.0	0.0	0.	9999.
	229	48.0	42.0	4.00	4.250	1.980	39.0	0.0	0.0	0.	9999.
	230	46.0	42.0	4.00	24.752	11.578	39.0	0.0	0.0	0.	9999.
	231	44.0	42.0	4.00	9.533	4.563	39.0	0.0	0.0	0.	9999.
	232	42.0	42.0	4.00	5.933	2.380	39.0	0.0	0.0	0.	9999.
	233	40.0	42.0	4.00	4.144	0.950	39.0	0.0	0.0	0.	9999.
	234	50.0	39.0	4.00	8.441	2.560	39.0	0.0	0.0	0.	9999.
	235	50.0	37.0	4.00	3.754	0.810	39.0	0.0	0.0	0.	9999.
	236	30.0	87.0	100.01	6.871	1.000	39.0	0.0	0.0	0.	9999.
	237	20.0	87.0	100.01	1.085	1.000	39.0	0.0	0.0	0.	9999.
	238	10.0	87.0	100.01	0.688	0.290	39.0	0.0	0.0	0.	9999.
	239	0.0	87.0	100.01	0.393	0.290	39.0	0.0	0.0	0.	9999.
	240	30.0	77.0	100.01	18.080	13.820	39.0	0.0	0.0	0.	9999.
	241	20.0	77.0	100.01	2.170	1.000	39.0	0.0	0.0	0.	9999.
	242	10.0	77.0	100.01	1.179	0.290	39.0	0.0	0.0	0.	9999.
	243	0.0	77.0	100.01	1.965	0.360	39.0	0.0	0.0	0.	9999.
	244	30.0	67.0	100.01	5.063	1.407	39.0	0.0	0.0	0.	9999.
	245	20.0	67.0	100.01	2.893	1.000	39.0	0.0	0.0	0.	9999.
	246	10.0	67.0	100.01	5.011	0.290	39.0	0.0	0.0	0.	9999.
	247	0.0	67.0	100.01	0.589	0.290	39.0	0.0	0.0	0.	9999.
	248	40.0	61.0	25.00	0.831	2.400	39.0	0.0	0.0	0.	9999.
	249	35.0	62.0	25.00	8.311	1.800	39.0	0.0	0.0	0.	9999.
	250	30.0	62.0	25.00	16.622	1.800	39.0	0.0	0.0	0.	9999.
	251	20.0	57.0	100.01	66.488	0.600	39.0	0.0	0.0	0.	9999.
	252	10.0	57.0	100.01	57.346	2.160	39.0	0.0	0.0	0.	9999.
	253	0.0	57.0	100.01	5.525	2.000	39.0	0.0	0.0	0.	9999.
	254	40.0	56.0	25.00	45.035	18.640	39.0	0.0	0.0	0.	9999.

TABLE 2.4(b) (Contd.)

	255	35.0	57.0	25.00	10.352	3.810	39.0	0.0	0.0	0.0	9999.
	256	30.0	57.0	25.00	10.804	28.428	39.0	0.0	0.0	0.0	9999.
	257	35.0	52.0	25.00	15.449	6.617	39.0	0.0	0.0	0.0	9999.
	258	30.0	52.0	25.00	45.710	6.310	39.0	0.0	0.0	0.0	9999.
	259	20.0	47.0	100.01	6.493	2.550	39.0	0.0	0.0	0.0	9999.
	260	10.0	47.0	100.01	5.102	1.860	39.0	0.0	0.0	0.0	9999.
	261	0.0	47.0	100.01	9.077	0.850	39.0	0.0	0.0	0.0	9999.
	262	35.0	47.0	25.00	28.756	6.976	39.0	0.0	0.0	0.0	9999.
	263	30.0	47.0	25.00	13.297	3.920	39.0	0.0	0.0	0.0	9999.
	264	35.0	42.0	25.00	63.391	4.785	39.0	0.0	0.0	0.0	9999.
	265	30.0	42.0	25.00	17.453	4.000	39.0	0.0	0.0	0.0	9999.
	266	20.0	37.0	100.01	4.638	2.550	39.0	0.0	0.0	0.0	9999.
	267	10.0	37.0	100.01	6.957	1.000	39.0	0.0	0.0	0.0	9999.
	268	0.0	37.0	100.01	24.863	2.000	39.0	0.0	0.0	0.0	9999.
	269	45.0	37.0	25.00	70.848	14.784	39.0	0.0	0.0	0.0	9999.
	270	40.0	37.0	25.00	21.828	6.290	39.0	0.0	0.0	0.0	9999.
	271	35.0	37.0	25.00	24.933	3.000	39.0	0.0	0.0	0.0	9999.
	272	30.0	37.0	25.00	16.622	3.000	39.0	0.0	0.0	0.0	9999.
	273	45.0	32.0	25.00	60.547	2.194	39.0	0.0	0.0	0.0	9999.
	274	40.0	32.0	25.00	108.274	0.936	39.0	0.0	0.0	0.0	9999.
	275	30.0	27.0	100.01	24.933	0.600	39.0	0.0	0.0	0.0	9999.
	276	20.0	27.0	100.01	6.610	1.040	39.0	0.0	0.0	0.0	9999.
	277	10.0	27.0	100.01	4.830	0.200	39.0	0.0	0.0	0.0	9999.
	278	45.0	27.0	25.00	24.933	3.000	39.0	0.0	0.0	0.0	9999.
	279	40.0	27.0	25.00	16.622	3.000	39.0	0.0	0.0	0.0	9999.
Light Industry	280	45.0	22.0	25.00	33.244	3.190	39.0	0.0	0.0	0.0	9999.
	281	40.0	22.0	25.00	8.311	12.000	39.0	0.0	0.0	0.0	9999.
	282	30.0	17.0	100.01	1.271	0.210	39.0	0.0	0.0	0.0	9999.
	283	20.0	17.0	100.01	2.542	2.110	39.0	0.0	0.0	0.0	9999.
	284	10.0	17.0	100.01	8.136	0.410	39.0	0.0	0.0	0.0	9999.
	285	45.0	17.0	25.00	0.508	0.410	39.0	0.0	0.0	0.0	9999.
	286	40.0	17.0	25.00	0.254	0.410	39.0	0.0	0.0	0.0	9999.
	287	40.0	7.0	100.01	0.0	0.200	39.0	0.0	0.0	0.0	9999.
	288	30.0	7.0	100.01	0.0	0.210	39.0	0.0	0.0	0.0	9999.
	289	20.0	7.0	100.01	0.0	0.200	39.0	0.0	0.0	0.0	9999.
	290	10.0	7.0	100.01	1.271	0.840	39.0	0.0	0.0	0.0	9999.
	291	52.0	36.0	1.00	1.670	0.890	39.0	0.0	0.0	0.0	9999.
	292	53.0	35.0	1.00	0.950	0.540	39.0	0.0	0.0	0.0	9999.
	293	52.0	35.0	1.00	1.770	0.970	39.0	0.0	0.0	0.0	9999.
	294	55.0	34.0	1.00	0.910	0.500	39.0	0.0	0.0	0.0	9999.
	295	54.0	34.0	1.00	0.680	0.410	39.0	0.0	0.0	0.0	9999.
	296	53.0	34.0	1.00	0.570	0.330	39.0	0.0	0.0	0.0	9999.
	297	52.0	34.0	1.00	0.500	0.280	39.0	0.0	0.0	0.0	9999.
	298	55.0	33.0	1.00	1.930	1.040	39.0	0.0	0.0	0.0	9999.
	299	54.0	33.0	1.00	2.090	1.160	39.0	0.0	0.0	0.0	9999.
	300	53.0	33.0	1.00	0.810	0.450	39.0	0.0	0.0	0.0	9999.
	301	52.0	33.0	1.00	0.510	0.290	39.0	0.0	0.0	0.0	9999.
	302	59.0	32.0	1.00	0.500	0.340	39.0	0.0	0.0	0.0	9999.
	303	58.0	32.0	1.00	0.510	0.290	39.0	0.0	0.0	0.0	9999.
	304	57.0	32.0	1.00	0.080	0.050	39.0	0.0	0.0	0.0	9999.
	305	56.0	32.0	1.00	0.520	0.300	39.0	0.0	0.0	0.0	9999.
	306	55.0	32.0	1.00	0.960	0.550	39.0	0.0	0.0	0.0	9999.

TABLE 2.4(b) (Contd.)

	307	54.0	32.0	1.00	1.430	0.800	39.0	0.0	0.0	0.	9999.
	308	53.0	32.0	1.00	2.370	1.300	39.0	0.0	0.0	0.	9999.
	309	52.0	32.0	1.00	1.840	1.010	39.0	0.0	0.0	0.	9999.
	310	61.0	31.0	1.00	0.510	0.290	39.0	0.0	0.0	0.	9999.
	311	60.0	31.0	1.00	0.510	0.290	39.0	0.0	0.0	0.	9999.
	312	59.0	31.0	1.00	0.640	0.370	39.0	0.0	0.0	0.	9999.
	313	58.0	31.0	1.00	0.630	0.410	39.0	0.0	0.0	0.	9999.
	314	57.0	31.0	1.00	0.520	0.340	39.0	0.0	0.0	0.	9999.
	315	56.0	31.0	1.00	0.960	0.550	39.0	0.0	0.0	0.	9999.
	316	55.0	31.0	1.00	4.520	2.560	39.0	0.0	0.0	0.	9999.
	317	54.0	31.0	1.00	0.960	0.600	39.0	0.0	0.0	0.	9999.
	318	53.0	31.0	1.00	0.940	0.530	39.0	0.0	0.0	0.	9999.
	319	52.0	31.0	1.00	1.510	0.810	39.0	0.0	0.0	0.	9999.
	320	50.0	37.0	4.00	6.148	0.810	39.0	0.0	0.0	0.	9999.
	321	50.0	33.0	4.00	2.533	0.950	39.0	0.0	0.0	0.	9999.
	322	50.0	32.0	4.00	4.155	1.045	39.0	0.0	0.0	0.	9999.
	323	50.0	29.0	4.00	1.920	1.040	39.0	0.0	0.0	0.	9999.
	324	52.0	29.0	4.00	4.850	2.710	39.0	0.0	0.0	0.	9999.
	325	54.0	29.0	4.00	4.170	2.260	39.0	0.0	0.0	0.	9999.
	326	56.0	29.0	4.00	3.110	1.700	39.0	0.0	0.0	0.	9999.
	327	58.0	29.0	4.00	8.120	4.390	39.0	0.0	0.0	0.	9999.
	328	60.0	29.0	4.00	7.560	4.110	39.0	0.0	0.0	0.	9999.
Light Industry	329	62.0	29.0	4.00	1.190	0.670	39.0	0.0	0.0	0.	9999.
	330	50.0	27.0	4.00	0.720	0.390	39.0	0.0	0.0	0.	9999.
	331	52.0	27.0	4.00	2.290	1.250	39.0	0.0	0.0	0.	9999.
	332	54.0	27.0	4.00	3.390	1.850	39.0	0.0	0.0	0.	9999.
	333	56.0	27.0	4.00	0.710	0.410	39.0	0.0	0.0	0.	9999.
	334	58.0	27.0	4.00	1.410	0.780	39.0	0.0	0.0	0.	9999.
	335	60.0	27.0	4.00	2.050	1.110	39.0	0.0	0.0	0.	9999.
	336	62.0	27.0	4.00	1.230	0.690	39.0	0.0	0.0	0.	9999.
	337	64.0	27.0	36.00	4.670	2.660	39.0	0.0	0.0	0.	9999.
	338	70.0	22.0	100.01	3.620	1.850	39.0	0.0	0.0	0.	9999.
	339	50.0	22.0	25.00	3.310	1.900	39.0	0.0	0.0	0.	9999.
	340	55.0	22.0	25.00	4.670	2.580	39.0	0.0	0.0	0.	9999.
	341	60.0	22.0	25.00	7.760	4.240	39.0	0.0	0.0	0.	9999.
	342	65.0	22.0	25.00	1.500	0.810	39.0	0.0	0.0	0.	9999.
	343	50.0	12.0	100.01	4.610	2.600	39.0	0.0	0.0	0.	9999.
	344	60.0	12.0	100.01	1.160	0.700	39.0	0.0	0.0	0.	9999.
	345	70.0	12.0	100.01	4.620	1.936	39.0	0.0	0.0	0.	9999.
	346	50.0	2.0	100.01	1.170	0.730	39.0	0.0	0.0	0.	9999.
	347	60.0	2.0	100.01	0.390	0.200	39.0	0.0	0.0	0.	9999.
	348	70.0	2.0	100.01	0.830	0.450	39.0	0.0	0.0	0.	9999.
	349	70.0	32.0	25.00	0.250	0.130	39.0	0.0	0.0	0.	9999.
	350	75.0	32.0	25.00	0.490	0.270	39.0	0.0	0.0	0.	9999.
	351	62.0	21.0	4.00	0.450	0.260	39.0	0.0	0.0	0.	9999.
	352	54.0	35.0	1.00	0.450	0.250	39.0	0.0	0.0	0.	9999.
	353	58.0	33.0	1.00	0.900	0.510	39.0	0.0	0.0	0.	9999.
TOTAL					0.71516E 04	0.20525E 04					
AREA SOURCE TOTAL					0.28038E 04	0.18660E 04					
POINT SOURCE TOTAL					0.43483E 04	0.18652E 04					

2.4 Predictions of Future Emissions Based on Economic Activity-related Emission Factors

A third alternative currently under study is to estimate emission factors by combining a land-use classification scheme with the SIC classification. These emission factors are based on present point source emission data (both large and small sources), SIC and employment-size classifications. Employment represents an easily obtained variable that reflects economic-activity levels. Seventy-six different land-use emission factors are developed representing 19 different SIC activities with 4 employment levels which indicate different economic activity levels and therefore different emission levels for each SIC classification. These factors thus account for the effect of such parameters as product types, productivity, technology, and fuel usage within each manufacturing classification on emission rates. Because of the wide range in these parameters within each SIC classification, there is a variance in the estimated value of the emission factor. However, the use of these factors to project future emissions eliminates some of the problem inherent in the use of zoning-based emission factors which do not give stable estimates of the emissions due to the development of zoned areas or in the use of the assumption that all new development will occur "in place." SIC projections can be used for the emission projection and the SIC-based emission factors should give estimates with less variability than the zoning-based estimate. A second advantage is that the growth of an SIC-activity can be projected in previously undeveloped areas. This approach may eliminate the problems inherent in the first two approaches.

The first step in the process of generating SIC-based emission factors is to determine the number of manufacturing firms in each SIC classification. Each year the U.S. Census Bureau publishes a document entitled "County Business Patterns." These documents represent a survey of industrial sources aggregated by state, county, and metropolitan statistical areas. These industries are listed by SIC numbers and employment-size classes. A summary of this data is published every four years in the Census of Manufacturing.

Based on the number of firms in each industrial class, a sample size for each SIC number to be surveyed is generated. The larger the number of sources the smaller the percent sample required. The actual sources surveyed should be selected randomly from all the sources within each SIC, employment-class category. A manufacturing directory listing the name, address, SIC number, and employment size of each industry within the survey region may be used to make this random selection.

A survey is then made of the industries in the sample to determine their present fuel use, and emissions are calculated for the set of industries selected in the random sample. The total emissions are divided by the

number of firms in that SIC and employment class sample to obtain an SIC-based emission factor. At this point, it is important to note that the data obtained in an emission inventory may be used to generate the emission factors instead of a special fuel use survey. However, only those pollution sources which were selected in the random sample of all sources in the region should be used. Otherwise, a bias is introduced by developing SIC emission factors based primarily on the larger sources usually found in standard emission inventories.

Once unbiased emission factors for each SIC employment class have been estimated from the sample, multiplication of the projected growth in that SIC employment class by the appropriate emission factor yields the total future emissions from that SIC source type within the region. The next step in the process is to sum the emissions from all source types within the region.

Finally, the total future emissions must be distributed throughout the region based on a land-use or zoning plan. The distribution scheme assumes that the future emissions from any SIC source type (e.g., heavy industry) are allocated to each areal unit (e.g., square mile) in the region, in proportion to the percent of land that is designated for that use. These percentages can be generated from zoning maps, comprehensive plans, land-use forecasts, or any other kind of development schemes.

Sample Calculation and Distribution of Emissions

Consider the fabricated metal products industry (SIC 34) with less than 20 employees. In Illinois there are 1248 firms with this classification.* A sample of 20 of these firms was used to develop the emission factors. The results are presented in Table 2.5. The emission factors are the average emissions for each pollutant. For example, the SO₂ factor is

$$0.22/20 = 0.011. \quad **$$

In the Chicago region there are 1062 of these firms. They are distributed by county as shown in Table 2.6. The emission figures are calculated by multiplying the emission factor given above by the number of firms in each county, e.g., for Cook County the emissions are

$$0.011 \times 901 = 9.9 \text{ (tons/yr).}$$

An estimated 57,000 tons of SO₂ are emitted each year from heavy industry in Cook County. Table 2.7 shows the SIC and employment classes that were assured to be restricted to heavy industrial areas. The 25-square mile area bound by 71st and 111th St. and Halsted and

*County Business Patterns 1969, CBP-69-15/Illinois.

**Only two significant figures used.

Burley (see Fig. 2.2) has 8.1% of the land zoned for heavy industry in Cook County. Therefore,

$$(0.081) \times (57,000) = 4600 \text{ tons/yr}$$

are estimated to be emitted from heavy industry in that area.

Since all other manufacturing can locate in light or heavy manufacturing zones, their emissions are distributed in proportion to the total area zoned for manufacturing in each grid. The emissions from heavy- and light-manufacturing in each grid are summed to obtain total emissions.

TABLE 2.5. Emission Data (tons/yr)
(SIC 34, employment 1-19)

Sample Number	SIC	Employment	Particulate	SO ₂	NO _x	HC	CO
1	3471	12	0.0270	0.0010	0.0000	0.0000	0.0010
2	3441	9	0.0063	0.0130	0.0240	0.0007	0.0008
3	3442	10	0.0210	0.0003	0.0000	0.0000	0.0008
4	3461	17	0.0041	0.0002	0.0000	0.0000	0.0002
5	3444	12	0.0110	0.0004	0.0000	0.0000	0.0004
6	3444	15	0.0150	0.0790	0.0720	0.0020	0.0020
7	3461	7	0.0037	0.0001	0.0000	0.0000	0.0001
8	3441	5	0.0080	0.0003	0.0000	0.0000	0.0003
9	3451	18	0.2900	0.0110	0.0000	0.0000	0.0110
10	3449	8	0.0001	0.0000	0.0000	0.0000	0.0000
11	3451	10	0.0003	0.0000	0.0000	0.0000	0.0000
12	3461	12	0.0062	0.0022	0.0036	0.0001	0.0003
13	3464	6	0.0150	0.0790	0.0720	0.0020	0.0020
14	3449	4	0.2600	0.0096	0.0000	0.0000	0.0096
15	3479	6	0.0110	0.0004	0.0000	0.0000	0.0004
16	3441	8	0.0011	0.0000	0.0000	0.0000	0.0000
17	3471	12	0.0150	0.0005	0.0000	0.0000	0.0005
18	3444	18	0.0019	0.0001	0.0000	0.0000	0.0001
19	3444	8	0.0170	0.0006	0.0000	0.0000	0.0006
20	3499	5	0.0090	0.0240	0.0430	0.0012	0.0012
Total			0.7227	0.2222	0.2146	0.0060	0.0313
Emission Factor			0.0360	0.0110	0.0110	0.0003	0.0015

TABLE 2.6. Emissions by County
(SIC 34, employment 1-19)

County	No. of Firms	SO ₂ Emissions (tons/yr)
Cook	901	9.90
Du Page	69	0.76
Kane	24	0.26
Lake	32	0.35
McHenry	24	0.26
Will	12	0.13
Total	1062	11.66 $\approx$ 12

TABLE 2.7. Heavy Industries

SIC	Employment	Type
22	≥ 250	Textiles
29	≥ 1	Petroleum
30	≥ 1	Rubber
31	≥ 100	Leather
32	≥ 1	Glass
33	≥ 1	Primary Metals
34	≥ 100	Metal Fabrication

Fig. 2.2. Chicago Source Identification Map. ANL Neg. No. 190-185.

Results

The above procedure for generating emission factors, estimating aggregate emissions in each county, and distributing them based on zoning was tested in the Chicago Air Quality Control Region. It should be noted that the survey procedure outlined above was not followed because of time constraints. Rather a statewide emission inventory of approximately 25% of the manufacturers was used as the sample space. Since this inventory is not representative of all industries in the state and random sampling was not always possible, the results generated are not final. Rather, they are presented here for demonstration purposes. In addition, the emission factors developed represent emissions from fuel combustion only. These factors are given in Table 2.8.

TABLE 2.8. Emission Factors (tons/yr)

SIC/Employment	1-19	20-99	100-249	≥250
	SO ₂	SO ₂	SO ₂	SO ₂
20	0.21	7.0	32.0	1900
22	0.0001	0.0064	0.0064	74
23	0.0089	0.0079	0.0079	8.3
24	0.0030	0.0030	35	40
25	0.0020	2.4	3.7	23
26	0.0440	19.0	60	960
27	0.0065	0.0065	0.7200	3.9
28	0.82	8.5	100	2800
29	2.1	21	510	4400
30	0.11	0.11	3.2	210
31	0.0001	0.0001	0.0001	22
32	0.037	2.9	91	380
33	0.031	3.7	5.3	360
34	0.011	0.19	0.82	130
35	0.0051	0.055	3.5	440
36	0.0002	0.052	1.3	190
37	6.3	6.3	8.5	920
38	0.0014	0.0014	0.0014	5.7
39	0.61	0.61	65	47

Using these factors and the County Business Patterns for 1968, an estimated 1190 tons/day of SO₂ was emitted from fuel combustion in the six county region. The actual emission inventory for 1968 shows SO₂ fuel combustion emission for the same region to be 905 tons/day. Assuming the IPP inventory to be correct, there is a 32% error in our estimate. Table 2.9 shows the results on a county level.

TABLE 2.9. SO₂ Emission by County (tons/day)

County	Emission Factor		% Error
	Estimate	IPP	
Cook	996	733	36
Du Page	25	15	67
Kane	45	3	1400
Lake	54	30	80
McHenry	12	2	500
Will	73	122	-40
Total	1205	905	32

As expected, the largest errors occur in areas with a small number of manufacturing plants. This emphasizes the fact that the emission factors do not represent accurate estimates of emissions from one or a few firms. As the number of manufacturing firms increase the accuracy of the estimates increases.

These results indicate that a land use based emission factor has promise for estimating emissions for a region with a large number of manufacturing firms. (It is felt that better estimates can be obtained using a random survey.)

An alternative to land-use emission factors for various industrial classifications is a land-use energy consumption factor. This latter parameter can be converted into emission using fuel use estimates or trends. It should be expected that energy consumption would have less variance than emissions within a given industrial class. Since variance in emissions is introduced by varying fuel usage to produce a given product, an energy consumption factor would remove this variation. Furthermore, these parameters could be applied throughout larger regions and possibly for the entire country. Further work in developing and testing techniques for generating land use based emission factors is continuing at Argonne under the Air Pollution-Land-Use Planning Project: Phase II.

2.5 Conclusions

Three methods for generating land use based emission inventories for projection purposes have been discussed in this section. The zoning classification method largely ignored the economic activity producing the pollution with the result that the variance in possible outcomes is too large within each class to be usefully summarized by one parameter of the distribution (e.g., expected value). The growth in place by SIC classification incorporates economic activity methods but is unsatisfying for developing regions. The third method of combining the SIC classification with employment size to reduce the variance in emission factors appears promising. Although more information is required with this technique, the data

appears readily available. Further testing this technique in the Chicago AQCR will continue in Phase II of the program.

It is important to note that none of the above approaches is likely to be entirely satisfactory for the land use oriented environmental planner. The fundamental problem is that conventional land use or economic activity classification systems were not designed to reflect waste discharge potential. Optimal use of a land use oriented environmental planning methodology therefore requires the formulation of a functional classification system in which economic and demographic sectors are grouped in terms of their waste discharge potential rather than on the basis of perceived qualitative similarity, economic interdependence or similarity of marketable output products. The possibility of developing alternative environmental land use classification systems will be pursued during Phase II of the Air Pollution-Land-Use Planning Project.

Compounding the problem of land use classification is the fact that large sources tend to cluster creating "hot spots." Tables 2.10 and 2.11 and Figs. 2.3 through 2.16 indicate this clustering for various zoning classes in the Chicago AQCR. Such clustering occurs for a variety of

TABLE 2.10. Chicago Region SO₂ Spatial Emission Distribution

Zoning Class	Percent of Emissions by Zoning Class	Total Square Miles Zoned for Each Class ^a
Total	50	11.63
	60	16.52
	75	49.19
	90	104.81
Heavy Industry	50	2.2
	60	3.7
	75	4.8
	90	9.5
Large Residential Commercial ^b	50	11.6
	60	15.3
	75	20.3
	90	26.0
Light Industry	50	16.0
	60	25.5
	75	44.8
	90	70.9

^aThe Chicago eight-county region contains approximately 4500 square miles.

^bThis class was not collected as part of the zoning inventory, but was estimated from region maps.

TABLE 2.11. Chicago Region Particulate Spatial Emission Distribution

Zoning Class	Percent of Emissions by Zoning Class	Total Square Miles Zoned for Each Class
Total	50	6.6
	60	10.5
	75	32.8
	90	82.2
Heavy Industry	50	2.0
	60	3.6
	75	5.0
	90	11.0
Large Residential	50	11.9
	60	16.5
Commercial ^a	75	20.2
	90	26.7
Light Industry	50	15.5
	60	26.6
	75	53.7
	86	81.8

^aThis class was not collected as part of the zoning inventory, but was estimated from region maps.

economic reasons, including access, physical resources, employment markets, product markets, etc. Thus, as indicated earlier, if overt legislative controls are insufficient to control such locations in the future, urban plans and public investment policies which tend to limit and disperse clustering must be formulated. The extent to which such clustering can be tolerated depends on the type of pollutant emitted, control possibilities, local topography, etc. Methods for assessing the capacity of a region for producing a certain product mix within a regional plan are needed.

Fig. 2.3. SO₂ Total Emissions. ANL Neg. No. 190-220.

Fig. 2.4. SO₂ Air Quality due to Total Emissions--Illinois Only. ANL Neg. No. 190-221.

Fig. 2.5. SO₂ Air Quality due to Total Emissions—Illinois and Indiana. ANL Neg. No. 190-222.

Fig. 2.6. SO₂ Heavy Industrial Emissions. ANL Neg. No. 190-223.

Fig. 2.7. SO₂ Air Quality due to Heavy Industrial Emissions—Illinois Only. ANL Neg. No. 190-224.

Fig. 2.8. SO₂ Air Quality due to Heavy Industrial Emissions—Illinois and Indiana. ANL Neg. No. 190-225.

Fig. 2.9. SO₂ Heavy Residential/Commercial Emissions. ANL Neg. No. 190-226.

Fig. 2.10. SO₂ Air Quality due to Heavy Residential/Commercial Emissions--Illinois Only. ANL Neg. No. 190-227.

Fig. 2.11. SO₂ Air Quality due to Heavy Residential/Commercial Emissions--
Illinois and Indiana. ANL Neg. No. 190-228.

Fig. 2.12. SO₂ Light Industrial Emissions. ANL Neg. No. 190-229.

Fig. 2.13. SO₂ Air Quality due to Light Industrial Emissions--Illinois Only. ANL Neg. No. 190-230.

Fig. 2.14. SO₂ Air Quality due to Light Industrial Emissions--Illinois and Indiana. ANL Neg. No. 190-231.

Fig. 2.15. SO₂ Power Plant Emissions. ANL Neg. No. 190-232.

Fig. 2.16. SO₂ Air Quality due to Power Plant Emissions—Illinois Only. ANL Neg. No. 190-233.

3. LAND-USE-BASED ANALYSIS OF REGIONAL AIR QUALITY

3.1 Introduction

The methods for generating emission growth projections discussed in the previous section all generate a spatial emission pattern based on land area. In this approach, individual point source emissions have been "homogenized" on a grid basis. Individual point source characteristics are lost in the process and thus some sort of "average" emission parameters must be estimated. This aggregation of point sources is necessary because of the impossibility of predicting exact locations and stack parameters of future point sources.

Air quality calculations based on this "homogenized" emission projection are performed using an atmospheric dispersion model. The Air Quality Display Model (AQDM) available from the Federal EPA was used for this purpose. Since AQDM handles point and area sources separately, it was necessary to test the sensitivity of the model for the assumptions made in averaging emission characteristics.

Given a dispersion model such as AQDM, a land-use plan or zoning inventory, and land-use-based emission inventory, current air quality is estimated by

$$\chi_k = \sum_m \sum_{\ell} \alpha_{\ell k}^m E_{\ell}^m F_{\ell}^m A_{\ell} + \beta_k, \quad (3.1)$$

where E_{ℓ}^m is the current emission density for land-use class m at location ℓ , and the rest of the definitions are the same as in Eq. 2.1.

It was required to test the sensitivity of the AQDM model to the use of the homogenized area source emission inventory. To carry out tests of this kind, the 1968 Chicago region AQDM point source emission inventory was aggregated on the AQDM area grid basis as was shown in Table 2.4(a). AQDM was then recalibrated using the modified emission file. Figures 3.1 and 3.2 show the calibration results and compares them with our previous runs (using the original point source inventory). It can be seen that the comparison is sufficiently close to warrant our using the modified emission file in areas where the grid squares are sufficiently small. Figures 3.3-3.6* compare the air quality isopleths resulting from the use of each of the emission files for both particulates and SO_2 . The Joliet area (lower left corner) is lost in the aggregation process because 100 square mile grids cover this area. The Chicago and Gary areas are preserved reasonably well, since these areas have fine (1 square mile) grids.

*The isopleths were drawn using the SYMAP display package.⁵ This program accepts discrete point data on a two-dimensional grid and interpolates to generate contour lines of constant value.

Fig. 3.1. Modified Sulfur Dioxide Calibration Based on 1968 Air Quality Data. ANL Neg. No. 190-103.

Fig. 3.2. Modified Particulate Calibration Based on 1968 Air Quality Data. ANL Neg. No. 190-104.

Fig. 3.3. Current Expected Sulfur Dioxide Annual Geometric Means* (uncontrolled emission inventory) and 12 Selected Receptors Using Point Source Inventory. ANL Neg. No. 190-105.

* $\mu\text{g}/\text{m}^3$.

Fig. 3.4. Current Expected Sulfur Dioxide Annual Geometric Means* (uncontrolled emission inventory) and 12 Selected Receptors Using Area Source Inventory. ANL Neg. No. 190-106.

* $\mu\text{g}/\text{m}^3$.

Fig. 3.5. Current Expected Particulate Annual Geometric Means* (uncontrolled emission inventory) and 12 Selected Receptors with Point Source Inventory. ANL Neg. No. 190-107.

* $\mu\text{g}/\text{m}^3$.

Fig. 3.6. Current Expected Particulate Annual Geometric Means* (uncontrolled emission inventory) and 12 Selected Receptors with Area Source Inventory. ANL Neg. No. 190-108.

* $\mu\text{g}/\text{m}^3$.

The assumption that the AQDM model can be used provided sufficiently small grids are used in high emission areas seems to be warranted. This condition, however, necessitates the development of methods for re-defining the AQDM geocode units in areas of expected future high emission development. Presently, in addition to the Argonne program, Willis et al.⁶ of ERT are investigating methods of adapting the AQDM grid system approach and aggregation methods to land-use studies of the New Jersey Hackensack Meadowlands.

3.2 Air Quality Projections Based on Land-Use Emission Inventory Methods

This section describes the development and partial testing of a land-use-based air quality computation and analysis system. The components of the system and the overall logical flow have been identified as shown in Fig. 3.7. A pilot version of this system has been constructed and tested, but refinement of the programs and methods will continue throughout Phase II of the project. The air quality projection scheme combines the emission projection techniques described in Section 2 with atmospheric dispersion models.

3.2.1 Air Quality Projections Using Zoning Emission Density Factors

The objective of the Phase I effort was to develop a system such as that depicted in Fig. 3.7, which would project maximum growth of both controlled as well as uncontrolled emissions, and display the resulting air quality. The purpose of this computer program was to be able to assess the effectiveness of proposed control regulations in maintaining air quality taking future development of the region into account.

To test a pilot version of the integrated computational system, a computer program (POLUT) was generated to list emission densities by zoning-use class on a square-mile basis for "developed" grid cells. The output of this program (shown in Figs. 3.8(a) and (b)) was used to generate estimates of "worst" and "average" future emissions for each grid square in the region. These two cases were based on the average and the highest emissions calculated from a given zoning classification for the 300 largest emitting grid squares in the region. These estimates were then used to calculate air quality by Eq. 2.1. A computer program (SMOG described in Appendix B) was written to perform the calculations. The resulting isopleths for the "worst" and average cases for SO₂ are shown in Figs. 3.10 and 3.11. These should be compared to the current expected air quality in the region as depicted in Fig. 3.4. It can be seen that the "worst case" approach projects dire consequences while the average case severely underestimates even current air quality.

As mentioned in Section 2, the difficulty is that uniform emission density factors based on zoning ignore the variance in type, level, and spatial distribution of economic activity. The SIC class-employment-zoning approach described in Section 2 has not yet been programmed into the system.

Fig. 3.7. Components of Land-Use-Based Air Quality Computation and Analysis System

300 LARGEST AREAS OF UNCONTROLLED PART EMISSION

GREATER THAN 0.00 TONS/DAY IND

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AREA NUMBER	ANNUAL EMISSIONS (TONS/DAY)	SOURCE LOCATION (MILES)		EMISSION SOURCE NUMBER	EMISSION RATE (TONS/DAY)	STANDARD INDUSTRIAL CLASS. NO.	HT (M)	STACK DATA			POL JUR
		HORIZONTAL	VERTICAL					DIAM (M)	VEL (M/SEC)	TEMP DEG. K	
1	152.20	56	33	432	102.00	3241.00	100.00	16.00	4.50	475.00	8.0
				433	50.20	3241.00	30.00	12.00	4.50	475.00	8.0
628	21.65	507.32	0.32	-2	0.00	2999.00	65.00	15.00	4.50	475.00	8.0
2	125.59	50	39	60	0.27	2140.00	53.40	4.00	3.70	285.00	2.0
				106	32.90	3312.00	33.00	10.50	3.00	530.00	2.0
				107	30.14	3312.00	52.00	15.00	5.00	450.00	2.0
				108	2.22	3312.00	35.00	10.00	3.00	650.00	2.0
				109	59.26	3312.00	52.00	6.10	3.00	700.00	2.0
				354	0.80	3312.00	45.60	28.10	2.21	464.00	2.0
509	17.87	184.70	0.98	-6	-0.00	2999.00	65.17	12.28	3.32	512.17	2.0
3	59.53	54	34	287	0.06	3312.00	68.70	0.80	3.07	464.00	9.0
				288	0.02	3312.00	68.70	0.12	3.07	469.00	9.0
				289	10.40	3312.00	44.00	9.80	3.07	464.00	9.0
				290	0.00	3312.00	70.50	0.28	3.37	492.00	9.0
				292	0.01	3312.00	45.80	7.55	1.83	464.00	9.0
				294	0.09	3312.00	45.80	15.50	2.45	464.00	9.0
				296	0.14	3312.00	45.90	14.00	3.37	492.00	9.0
				297	0.0	3312.00	42.80	5.00	2.37	492.00	9.0
				306	0.01	3312.00	20.00	10.00	0.50	492.00	9.0
				307	0.02	3312.00	40.00	10.40	2.00	464.00	9.0
				308	0.68	3312.00	52.00	16.90	2.60	464.00	9.0
				316	0.19	3312.00	88.60	10.30	3.40	285.00	9.0
				317	0.09	3312.00	52.00	6.20	2.60	464.00	9.0
				318	0.68	3312.00	52.00	22.20	2.60	464.00	9.0
				319	34.30	3312.00	52.00	18.00	2.60	464.00	9.0
				438	1.13	3312.00	36.60	10.70	4.00	355.00	9.0
				440	11.30	3312.00	10.00	3.10	5.00	285.00	9.0
				447	0.40	3312.00	42.80	9.40	6.73	530.00	9.0
570	8.43	50.52	1.58	-12	-0.00	2999.00	68.79	9.46	3.03	448.22	9.0
4	58.91	49	37	64	0.60	2040.00	62.50	4.00	3.70	285.00	2.0
				98	4.33	3312.00	35.00	10.50	3.00	530.00	2.0
				99	2.47	3312.00	40.00	10.00	3.50	530.00	2.0
				100	14.56	3312.00	52.00	15.00	4.50	450.00	2.0
				101	1.53	3312.00	20.00	1.00	5.00	300.00	2.0
				110	5.92	3312.00	52.00	10.50	3.00	530.00	2.0
				111	6.58	3312.00	52.00	10.00	3.50	530.00	2.0
				112	0.82	3312.00	52.00	15.00	3.00	450.00	2.0
				113	20.55	3312.00	20.00	1.00	5.00	300.00	2.0
				352	1.26	3312.00	18.00	16.60	1.03	464.00	2.0
				378	0.29	3909.00	33.00	12.40	1.70	464.00	2.0
544	8.43	90.64	2.63	-11	-0.00	2999.00	39.68	9.65	3.25	439.35	2.0

Fig. 3.8(a). Sample Output—Particulate Emission Density Estimate. ANL Neg. No. 190-109.

300. LARGEST AREAS OF UNCONTROLLED SO₂ EMISSION DENSITY GREATER THAN 0.00 TONS/DAY

IND

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AREA NUMBER	ANNUAL EMISSIONS (TONS/DAY)	SOURCE LOCATION (MILES) HORIZONTAL VERTICAL	EMISSION SOURCE NUMBER	EMISSION RATE (TONS/DAY)	STANDARD INDUSTRIAL CLASS. NO.	HT (M)	STACK DATA			PUL JUR
							DIAM (M)	VEL (M/SEC)	TEMP DEG. K	
1	115.83	53 33	273	0.45	2911.00	60.00	1.00	0.30	919.00	9.0
			274	11.40	2911.00	30.00	0.30	1.00	811.00	9.0
			277	16.70	2911.00	18.00	5.40	1.80	464.00	9.0
			280	68.00	2911.00	50.00	5.00	2.50	464.00	9.0
			423	12.51	2911.00	40.00	0.20	1.30	811.00	9.0
			425	5.87	2911.00	41.00	2.73	2.30	811.00	9.0
			429	0.90	2911.00	38.00	8.20	3.50	875.00	9.0
575	12.95, 12.95	772.20	0.15	-1	9992.00	39.57	3.26	1.81	720.43	9.0
2	23.81	53 30	269	0.11	2819.00	9.00	1.81	1.00	492.00	10.0
			419	23.70	2819.00	90.00	7.50	1.80	333.00	10.0
599	2.65, 15.53	476.14	0.20	-2	9992.00	62.59	5.65	1.56	512.50	10.0
3	166.22	53 35	271	19.00	2820.00	30.00	7.00	2.45	533.00	7.0
			276	6.77	2911.00	40.00	1.00	2.30	530.00	9.0
			281	13.90	2911.00	45.00	10.80	2.50	464.00	9.0
			422	0.0	2820.00	35.00	5.00	1.60	450.00	7.0
			424	10.00	2911.00	62.00	2.92	2.60	811.00	9.0
			427	22.30	2911.00	65.00	9.00	2.50	700.00	9.0
			428	96.25	2911.00	55.00	12.20	2.60	420.00	7.0
567	18.75, 35.25	224.29	0.55	-7	9992.00	67.43	6.85	2.36	558.29	8.1
4	60.61	56 33	432	36.50	3241.00	100.00	16.00	4.50	475.00	8.0
			433	24.11	3241.00	30.00	12.00	4.50	475.00	8.0
628	6.75, 41.65	222.03	1.25	-2	9992.00	65.00	14.00	4.50	475.00	8.0

Fig. 3.8(b). Sample Output--SO₂ Emission Density Estimate. ANL Neg. No. 190-110.

RECEPTOR NUMBER	RECEPTOR LOCATION (X, Y)	POWER PLANT CLASS	AREA IND CLASS	AREA LT IND CLASS	AREA R/C CLASS	AIR QUALITY		
		EMISSION DENSITY	EMISSION DENSITY	EMISSION DENSITY	EMISSION DENSITY	COMPUTED	STANDARD	EXCEEDED
		FACTORS	FACTORS	FACTORS	FACTORS			
		CONTRIB	TOTAL	CONTRIB	TOTAL	CONTRIB	TOTAL	
		FACTORS	CONTRIB	FACTORS	CONTRIB	FACTORS	CONTRIB	
150	85.3 114.21	12.5221	4.6451	1.2051	60.4551	4.1771	40.6651	119.6671
151	85.3 124.11	6.6231	2.3081	2.4641	89.2171	1.5951	15.7571	7.6721
152	85.3 130.61	7.4871	2.5131	3.2561	109.2811	2.1011	19.2531	141.9661
153	85.3 137.01	8.4591	2.6511	4.3051	135.4051	2.7811	23.8751	180.7051
154	85.3 143.41	5.5591	2.9401	6.2341	183.4771	4.1001	32.9421	257.5471
155	85.3 149.81	11.4231	3.1251	9.5141	265.9671	4.0221	61.6561	327.2651
156	85.3 156.31	10.5561	3.0251	12.2631	338.5671	6.4381	48.5221	417.4451
157	85.3 162.81	12.9341	3.6711	4.5191	241.8231	6.2731	49.6151	340.6311
158	85.3 169.21	15.0741	4.6491	6.0871	177.9341	6.3561	50.7271	229.7551
159	85.3 175.61	18.1791	5.0201	4.9191	146.7311	6.3871	52.0111	236.8151
160	85.3 182.11	19.6531	5.2011	4.3901	123.3261	5.5541	49.5701	202.2101
161	85.3 188.51	20.0951	6.7471	3.2711	102.5551	5.6221	48.2021	183.2561
162	85.3 194.91	16.0241	5.1961	2.6851	87.0911	5.0911	45.0731	159.8371
163	85.3 201.41	15.2331	5.1371	2.261	75.4121	4.4261	40.7451	139.8111
164	85.3 207.81	13.0641	4.6261	1.9391	65.1221	3.8371	37.0421	121.5931
165	85.3 214.21	11.2291	4.2301	1.5221	59.2221	3.2221	33.8521	105.5261
166	91.7 24.11	5.9081	2.2061	2.1081	81.7361	1.4421	14.6981	107.1891
167	91.7 30.61	6.6581	2.3151	2.7581	95.9471	1.8381	17.4571	127.6111
168	91.7 37.01	7.6991	2.4941	3.6581	118.5131	2.4281	21.4721	160.3961
169	91.7 43.41	9.0121	2.7211	5.3821	162.5261	3.4811	28.6981	220.6541
170	91.7 49.81	2.6651	2.7211	8.9611	254.1381	5.0141	30.2121	343.5471
171	91.7 56.31	11.0931	3.1251	8.7951	249.6171	4.8801	37.8121	341.2521
172	91.7 62.81	12.2611	2.8921	6.4211	188.3671	4.4681	35.7831	263.1511
173	91.7 69.21	13.7941	4.1461	4.8301	146.5701	4.3651	36.1581	278.8091
174	91.7 75.61	13.4541	4.2211	3.8481	120.3431	4.2671	36.4431	243.3991
175	91.7 82.11	14.2321	4.5421	3.1651	101.2271	4.0591	35.6701	222.1521
176	91.7 88.51	14.1721	4.6391	2.6591	89.4591	3.8821	35.1411	214.4811
177	91.7 94.91	12.2031	4.2251	2.2541	77.4071	3.5931	33.6861	177.0271
178	91.7 101.41	11.4931	4.1031	1.9081	68.1031	3.2431	31.6021	153.3371
179	91.7 107.81	10.5141	3.9361	1.5921	59.5371	2.9061	29.7151	132.2501
180	91.7 114.21	9.2401	3.6531	1.3671	53.2741	2.5291	27.3161	111.3011
181	98.1 24.11	5.4631	2.1111	1.9281	74.7651	1.2951	13.7061	8.6661
182	98.1 30.61	6.2551	2.2821	2.3281	84.7591	1.6051	15.6011	11.7271
183	98.1 37.01	7.4831	2.5201	3.0731	103.4891	2.0581	18.9191	15.4121
184	98.1 43.41	9.4731	2.7991	4.0931	129.2711	2.6501	22.9011	20.5471
185	98.1 49.81	11.2081	2.3241	5.3511	155.1251	3.0031	28.6311	23.7121
186	98.1 56.31	11.4621	3.4961	5.1041	155.6861	3.0921	25.7491	24.0361
187	98.1 62.81	11.8641	3.7071	4.2581	132.9831	3.1461	26.8441	22.9311
188	98.1 69.21	11.5141	3.6941	3.6281	116.0921	3.1191	27.2471	21.2421
189	98.1 75.61	10.6821	3.5251	3.0501	100.6481	3.0331	27.3201	18.6971
190	98.1 82.11	11.1821	2.3151	2.5321	86.5521	2.9891	27.8241	16.8851
191	98.1 88.51	10.7591	2.1231	2.1531	74.2111	2.7891	26.9551	14.7431
192	98.1 94.91	9.5601	2.6541	1.8501	67.8651	2.6441	26.4421	13.5151
193	98.1 101.41	8.7491	2.3641	1.5781	60.3361	2.4641	25.7191	12.6131
194	98.1 107.81	8.4471	3.3791	1.3631	54.7121	2.2141	24.1821	11.4181
195	98.1 114.21	7.6521	2.2121	1.1821	49.7961	2.0251	23.2111	10.2751
196	104.6 24.11	4.5821	2.0321	1.6521	67.3171	1.1431	12.7171	8.6801
197	104.6 30.61	5.5671	2.2851	1.9821	75.5331	1.3771	14.3221	10.6041
198	104.6 37.01	7.3531	2.6101	2.5081	89.0451	1.6731	16.2131	12.9631
199	104.6 43.41	6.7371	2.0251	2.7651	95.1931	1.9311	18.1471	15.6671

Fig. 3.9. Maximum SO₂ Annual Geometric Means (uncontrolled SO₂ emission factors recorded at 237 receptor stations). ANL Neg. No. 190-117.

Fig. 3.10. Projected SO_2 Annual Geometric Means (uncontrolled Emission inventory-Chicago average emission density factors). ANL Neg. No. 190-115.

Fig. 3.11. Projected Maximum SO₂ Annual Geometric Means (uncontrolled emission inventory). ANL Neg. No. 190-116.

3.2.2 Air Quality Projections Using Economic Growth Factors

The "growth in place" method for estimating emission growth is the simplest technique for incorporating the growth of economic activity into air quality projections. Emission factors estimation and the resulting area emission inventory was described in Section 2.2. The growth in place method was easily incorporated directly into the AQDM program as an option as shown in Fig. 3.12. Isopleths of projected air quality using this program are shown in Fig. 3.13. As can be seen from the figure, the technique remains unsatisfactory for projecting the rapidly growing area near Joliet. The extent to which this is due to the large grids covering that area remains to be tested.

3.3 Use of Probabilistic Methods for Evaluating Land-Use Plans and Air Pollution Control Policies

The methods for computing expected emission density factors described in previous sections ignore the variance in emission patterns that could occur given a specific land use or zoning plan. The crucial question regarding the effectiveness of any control strategy is: Can the strategy, in addition to being technologically feasible, maintain air quality in a developing region? What is sought is a confidence level estimate for air quality achievement and maintenance.

Projection techniques and models discussed earlier are necessarily partial in nature in that the economic and developmental forces producing changing emission patterns are difficult to incorporate in the analysis. An alternative to building more sophisticated emission estimation models using causal economic and developmental variables is to view the location of future emissions as essentially a random variable. When approached in this manner, very simple land-use classification systems such as zoning may be useful. This approach is explored in this section.

Fig. 3.12. Growth-in-place Computation Flow

3.3.1 Land-Use-Based Emission Density Probability Distributions

The Chicago region was divided geographically into two categories--developed (D) and undeveloped (U). Undeveloped land includes open space, agriculture, etc., from which emissions are negligible. Developed land was

Fig. 3.13. Projected SO₂ Annual Geometric Means* (uncontrolled emission inventory) for 1980. ANL Neg. No. 190-186.

* $\mu\text{g}/\text{m}^3$.

correlated with present emissions and the 300 largest emitting square miles for each zoning type was classified "developed."

A small computer program was prepared to list in descending order emissions in each "developed" square mile and operates on both controlled and uncontrolled emissions as shown in Fig. 3.14. Emission source distributions are shown for both SO₂ and particulates for light and heavy industrial zoning classes in Tables 3.1 and 3.2. Table 3.2 shows the shift in the emission source distributions after a proposed set of regulations has been applied.

Fig. 3.14
Generation of Emission Density Frequency Distributions

TABLE 3.1. Emission Density Frequency Data for Uncontrolled Emissions

	No. of Miles	Tons/day/mi ²	Zoning Class
SO ₂	269	0-10	HI
	25	10-100	
	6	100-1000	
	6	>1000	
	265	0-10	LI
	15	10-20	
	11	20-30	
	9	30-40	
	0	>40	
Part	274	0-10	HI
	24	10-100	
	2	100-1000	
	0	>1000	
	282	0-10	LI
	18	10-20	
	0	>20	
	0	>20	

TABLE 3.2. Emission Density Frequency Data for Controlled Emissions

	No. of Miles	Tons/day/mi ²	Zoning Class
SO ₂	284	0-10	HI
	11	10-100	
	3	100-1000	
	0	>1000	
	300	0-10	LI
	0	10-20	
	0	20-30	
	0	30-40	
	0	>40	
Part	297	0-10	HI
	3	10-100	
	0	100-1000	
	0	>1000	
	300	0-10	LI
	0	10-20	
	0	>20	
	0	>20	

These distributions can be interpreted as the probability that an emission density (tons emitted/hr-mi²) will occur if a square mile is developed for either heavy or light industry in the future. These distributions can be applied to assess probable emission growth by using them with regional growth projections of heavy or light industrial development. The AQDM code could then be applied to arrive at a confidence level that air quality will be met and maintained in the region; given, 1) the projected levels of industrial development, 2) the probability distribution that such development will induce a certain level of emission growth (derived from tables similar to 3.1 and 3.2), and 3) the control regulations regarding emissions. The required air quality calculation is described in the next section.

3.3.2 Developing Air Quality Confidence Estimates

Given that emission densities are a random variable $\hat{E}_\ell^m$, derived from an emission source distribution as described above, air quality becomes a random variable which is given by a linear combination of random variables as follows:

$$\hat{\chi}_k = \sum_m \sum_\ell \alpha_{\ell k}^m \hat{E}_\ell^m F_\ell^m A_\ell + \beta_k, \quad (3.2)$$

where $\hat{E}_\ell^m$ is the random emission density for land-use class m in location ℓ that is selected from the empirically derived probability distribution of present emission patterns (Figs. 3.1 and 3.2), and the rest of the definitions are the same as in Eq. 4.1.

What is sought in controlling emissions due to future development is that

$$\Pr(\hat{\chi}_k \leq \hat{\chi}) \geq \beta \quad (3.3)$$

where β is some prescribed confidence level that the air quality standard, $\hat{\chi}$, will be achieved and maintained for any growth pattern in land development (e.g., $\beta = 0.95$).

A Monte Carlo type of simulation can be performed to generate these confidence levels by using different values of E^m selected from the emission source probability distribution. Repeated runs using different values of E^m will in effect constitute "growth experiments" for the region. These calculations are quite rapid once the coupling coefficients, $\alpha_{\ell k}^m$, have been computed and stored in memory. Program SMOG can be easily modified to do the calculations.

This program allows two very important questions to be asked regarding proposed control regulations: (1) With what confidence can

regulations maintain air quality as regional growth proceeds (time dependence case)? (2) With what confidence can control regulations maintain air quality if the region develops to full planned capacity (limiting case)? The latter case can be computed in a straightforward manner by assuming all undeveloped land is developed. The former case must be combined with land development projections.

3.4 Conclusions

The linkage of techniques for projecting land-use-based emission inventories with the AQDM dispersion model is reasonably straightforward excepting for the geocode problem. It remains to define criteria for selecting sufficiently fine grid sizes for the dispersion model so that an accurate representation of source patterns is retained and yet not so fine as to prohibit the dispersion model from running on the computer. Further investigation in this area will continue in Phase II of the project.

No clearly acceptable method for estimating future emissions has yet been tested with the AQDM program. The technique of combining economic type and activity level with zoning is currently being incorporated into the system and will be tested shortly. The degree to which the use of such techniques can affect the selection of control strategies for implementation plans is yet to be determined.

This section also introduced the alternative of developing air quality confidence estimates instead of expected value projections of air quality. These estimates can be used in assessing the effectiveness of control regulations in maintaining air quality in the face of urban growth. However, little has been done to investigate the possibility of employing risk analysis in environmental policy-making.

4. THE DEVELOPMENT OF LAND-USE-BASED AIR POLLUTION CONTROL POLICIES

4.1 Introduction

Air pollution emissions are generated by manufacturing facilities, commercial facilities, service facilities, and residences in urban areas and by the transportation systems required to service these activities. Pollution concentrations at particular points in the urban area are determined by the size and location of the various activities that take place in an urban region and by the dispersion properties of the atmosphere. For present purposes, the latter is assumed to be described by the AQDM model discussed in the previous section. In this section, the discussion centers around the problem of control strategy design and the possible means for effecting control by mechanisms that adjust or regulate the spatial patterns and/or intensities of regional activity.

The case for utilizing land-use controls for limiting air pollution has been summarized by Croke and Roberts. It is based on three premises; namely, that land-use controls will:

1. Insure long-term maintenance⁷ of air quality standards;
2. Tailor emission control regulations to the character and projected growth of the region and thus conforms to the existing and projected demographic and economic design of the region;
3. Permit regional planners to evaluate revised growth patterns and thus revised emission control regulations, especially in the development of unincorporated areas.

The crucial point is that society often views the physical boundaries of a particular plot of land as the only capacity constraint on the intensity of land development. Acting independently, owners of land develop it for the most profitable activity and to the most profitable intensity level. The external effects of land use, which may be largely ignored by the individual land owner, include noise, liquid, gaseous, and solid wastes, fire hazards, congestion, and esthetic and psychological effects.

Federal ambient air quality standards place some form of limit on the amount of pollution-producing activity that can ever take place in a region. Source control of emitters based on per source regulations can allow future higher levels of land-use intensity to be reached than would now be permissible, but the exact relationship between the stringency of such regulations and the restrictions of development is not known. If air pollution control technology attained perfect collection efficiency, the land-use development would not be constrained by air pollution considerations, of

course. However, as long as control technology is less than perfectly efficient, the environmental impact of land use must be considered.

The determination of land use environmental capacity limitations as functions of space to preserve regional environmental quality over time is presently an unsolved problem. This section discusses some approaches to the problem, some of which will be pursued in more detail under Phase II of the Air Pollution-Land-Use Planning Project.

4.2 Land-Use-Based Emission Control Policies

As in previous sections, it is assumed that air quality is calculated by

$$\chi_k = \sum_m \sum_{\ell} \alpha_{\ell k}^m E_{\ell}^m F_{\ell}^m + \beta_k, \quad (4.1)$$

where the definitions are the same as given in Eq. 2.1.

From this relationship it can be seen that control measures that either affect the amount of emissions per unit of land (E_{ℓ}^m) or the land area allocated to a particular land use (F_{ℓ}^m) can be used to effect an improvement in regional air quality. Four types of control affecting either emissions per unit land or land-use patterns are discussed in this section:

1. Point source controls to reduce emission densities (E_{ℓ}^m).
2. Emission density regulations to reduce emission density (E_{ℓ}^m).
3. Zoning to alter land-use patterns (F_{ℓ}^m).
4. Public investment to alter land-use patterns (F_{ℓ}^m).

4.2.1 Point Source Controls Aimed at Reducing Emissions per Unit Land

The method currently employed for instigating air pollution legislation is to design what is known as a "point source" control strategy. Such a regulation requires plants of a particular size to control to a prescribed degree of efficiency. These regulations affect the emission density factors, E_{ℓ}^m , and hence present and future air quality. The procedure for evaluating the effectiveness of point source control regulations is shown in Fig. 4.1.

The usual method for deriving point source emission limitations is to sample several "well-controlled" plants in a given area to determine feasible control levels. The Bay Area curve for particulate control as a function of process weight is the most popular example. This method may be criticized because it ignores the locational aspects of emission patterns and the possibility of geographical concentrations of sources. Future spatial emission patterns due to development of the area may produce very

high emission density factors in a given area and consequently expected emissions that violate air quality constraints. If per source control regulations have been passed before such development takes place, the only way of maintaining air quality standards is either to pass new per source standards after the development has occurred or to regulate the amount of land that can be developed for particular uses (i.e., the F_{ℓ}^m), in areas where air quality is likely to be exceeded by further development.

This type of approach of course requires that one can project the locations of future growth in the region so that development can be restricted from local areas without endangering the development of the entire region. The growth in place projection method (described in Section 2) using Office of Economic Development projections has been incorporated into the AQDM (as shown in Fig. 4.2) to project an emission map for the year 1980. Sample air quality results are shown in Fig. 4.3 for one set of proposed Illinois per source control regulations. The control regulations appear to be effective through 1980. Projected air quality results for the localized growth restriction method of control will be displayed when the activity-based emission factors approach is programmed for the computer.

4.2.2 Emission Density Regulations--Direct Control

Emission density regulations are a restriction on the amount of emissions per unit of land area. They take the form of emission density constraints; for example, a regulation could be enacted forbidding emission

Fig. 4.1. Control Strategy Evaluation Procedure

Fig. 4.2. Logical Flow and Component Computer Programs of Air Pollution Planning Model

of more than 20 tons per day per acre of land of SO_2 . Such a regulation would require that either a large emitter reduce the number of tons a day emitted or have sufficient property to reduce the emissions per acre to acceptable levels.

Such density regulations are akin to zoning performance standards, first set forth by O'Harrow⁸ in 1951. Zoning itself has a long history in the attempt to separate and isolate nuisance generating activity, dating back to a 1916 New York City ordinance.

Croke and Roberts⁷ have suggested that emission density limits for a region can be designed assuming a land-use or zoning plan has been specified. Note that emission density limits can place an indirect restriction either on the amount of particular activity that can take place on a given plot of land or the required number of acres to carry on certain pollution producing activities. For example, steel production could require that a certain number of acres around the plant is not developed for industrial purposes. It is easy to see that environmental quality constraints introduced in this manner could have considerable impact on shaping the landscape of urban areas. A discussion of this aspect is deferred to Section 6.

A specific emission density regulation was tested for the Chicago program in Phase I. To reiterate the basic land-use oriented diffusion equation, let F_ℓ^m be specified as the fraction of land devoted to use m in geocode unit ℓ as before: let $\hat{\chi}_k$ represent the ambient air quality standard and E^m the emission density regulation for land-use class m (such as steel production). Then we are constrained as follows:

$$\chi_k \geq \sum_m \sum_\ell \alpha_{\ell k}^m F_\ell^m E^m \quad (4.2)$$

or

$$\left. \begin{aligned} \hat{\chi}_k &\geq \sum_m E^m \left\{ \sum_\ell \alpha_{\ell k}^m F_\ell^m \right\} \\ \text{or} \quad \hat{\chi}_k &\geq \sum_m P_k^m E^m \end{aligned} \right\} \quad (4.3)$$

$$\text{where } P_k^m = \left\{ \sum_\ell \alpha_{\ell k}^m F_\ell^m \right\}.$$

It is assumed that emission density limits could be set for both light (LI) and heavy (HI) industry and that an air quality standard for SO_2 has been established, then Eq. 4.3 describes the tradeoffs between allowable light and heavy industrial emission density standards for a given air quality standard. A standard of $80 \mu\text{g}/\text{m}^3$ for SO_2 was set and a graphical display of this tradeoff for the

Fig. 4.4. Feasible Region of Emission Density Limits for Heavy (HI) and Light (LI) Industry Only

Chicago region is shown in Fig. 4.4. If it is assumed that light industrial emissions are not allowed, the figure indicates that a 16-tons/day/ mi^2 emission density limit for all heavy industrial emissions can be tolerated for the $80 \mu\text{g}/\text{m}^3$ standard. (Power plants are assumed to be operating uncontrolled.)

A heavy industrial emission density limit of 20 tons/day/ mi^2 was tested for Chicago. Figure 4.5 shows the air quality resulting from this policy. The current estimated area of land zoned for heavy industrial use in the Chicago region is 114 square miles. The "allowable" limit for total heavy industry SO_2 emissions is therefore $114 \times 20 = 2280$ tons/day. Actual heavy industry (point source) SO_2 emissions in the Chicago region total approximately 1150 tons/day. If it were possible to spatially redistribute these emissions, the standards could be easily met. This exercise indicates the feasibility of using local land-use planning to achieve adaptive control of spatial emission patterns for the purpose of maintaining air quality standards.

It is interesting to note that if the 20-ton/day/ mi^2 limit were enacted into law, given the current spatial emission pattern, 26 square miles comprising 91.1% of heavy industrial SO_2 emissions would be affected. The total emission reduction would be approximately 633 tons/day or 55% of current emissions. Hardest hit would be the steel mills of south Chicago and Gary and the oil refineries, not only because they are large emitters but also because they are concentrated spatially.

Several questions still remain before the emission density approach can be applied. First, emission density limits must be technologically feasible. Perhaps feasible limits can be determined by sampling individual plants in each zoning classification and relating emissions to land area. This method is similar to that of designing feasible point source regulations based on process weight mentioned previously.

Administratively, emission density regulations remain a problem. Some counties (Cook and Will) in the Chicago Air Quality Control Region have proposed density regulations. The Cook County performance standards for particulate matter are shown in Table 4.1. Just how they can be administered and enforced remains an open question. One possible role for emission

Fig. 4.5. SO₂ Expected Annual Geometric Means: Heavy Industrial Emission Density = 20 tons/day/mi²
 (light industrial and residential/commercial emissions assumed zero--no power plant control).
 ANL Neg. No. 190-188.

TABLE 4.1. Performance Standards by Control Zone

Zone 1

In unincorporated areas includes all residential and business districts and the M1 manufacturing district, as established and defined in the Cook County Zoning Ordinance. In incorporated areas includes residential, business, and restricted manufacturing districts, or the most restrictive manufacturing district as defined in the applicable local zoning ordinance.

Particulate Matter The rate of emission of particulate matter from all sources within the boundaries of any lot shall not exceed a net figure of 1 lb/acre of lot area during any one hour, after deducting from the gross hourly emission per acre the correction factor set forth in the following table:

Allowance for Height of Emission^a

<u>Height of Emission above Grade (ft)</u>	<u>Correction (pounds per hour per acre)</u>
50	0.01
100	0.06
150	0.10
200	0.16
300	0.30
400	0.50

Zone 2

In unincorporated areas includes the M2 and M4 manufacturing districts, as established and defined in the Cook County Zoning Ordinance. In incorporated areas includes any general manufacturing district other than the most restrictive and most intensive manufacturing district as defined in the applicable local zoning ordinance.

Particulate Matter The rate of emission of particulate matter from all sources within the boundaries of any lot shall not exceed a net figure of 3 lb/acre of lot area during any one hour, after deducting from the gross hourly emission per acre the correction factor set forth in the following table:

Allowance for Height of Emission^a

<u>Height of Emission above Grade (ft)</u>	<u>Correction (pounds per hour per acre)</u>
50	0
100	0.5
150	0.8
200	1.2
300	2.0
400	4.0

Zone 3

In unincorporated areas includes the M3 manufacturing district as established and defined in the Cook County Zoning Ordinance. In incorporated areas includes heavy manufacturing districts or the most intensive manufacturing districts as defined in the applicable local zoning ordinance.

Particulate Matter The rate of emission of particulate matter from all sources within the boundaries of any lot shall not exceed a net figure of 8 lb/acre during any one hour, after deducting from the gross hourly emission per acre the correction factor set forth in the following table:

Allowance for Height of Emission^a

<u>Height of Emission above Grade (ft)</u>	<u>Correction (pounds per hour per acre)</u>
50	0
100	0.5
150	1.5
200	2.4
300	4.0
400	8.0

^aInterpolate for intermediate values not shown.

density limits are as guidelines to be used in conjunction with enforceable point source regulations rather than regulations themselves. In this capacity, they can be used for planning purposes and as a possible signal when localized pockets of industrial growth may present air quality degradation problems. Local officials could use them to induce more stringent control in expected industrial clusters (e.g., industrial parks) than would be required in isolated sites under the normal point source law. A proposed case study of Will County in Illinois as part of Phase II of the Air Pollution-Land-Use Planning Project may shed additional light on this subject.

4.2.3 Land-Use Planning or Zoning--Direct Control

In the previous sections it was assumed that a land-use plan or zoning ordinance was specified and could not be easily modified, and controls in the form of emission density limits and/or point source regulations were assigned to meet air quality standards. It may be possible, however, to accept insufficiently controlled levels of emission density and modify the type of land use in localized areas of the region. This approach may be especially useful when point source regulations are combined with projected land use or zoning plans that generate excessive emissions (i.e., too much land is allocated to high-emitting uses). In this case, urban planners can then adjust the spatial land-use plan to meet air quality standards.

Controlling air pollution via adjustments in land use or zoning implies that the land plan be strictly followed. It may be stated that environmental constraints yield, possibly for the first time, reasons for strict adherence to zoning regulations. Although zoning has had an impact on urban development, all too frequently local zoning plans appear to bear little consistent relationship to actual land use. Zoning variances become the rule rather than the exception because either political jurisdictions yield to economic pressures or do not reflect a comprehensive development plan indicating community preference for land development. Land-use allocations and zoning for environmental control now provide new impetus for tempering such economic pressures.

It is essentially the interface between the urban planners and the air pollution control agencies that needs definition if this control method is to be used. Standardized procedures for evaluating comprehensive plans for growth on a municipal, county, or regional level are needed. Output must be in a form that is, in turn, useful to the planner in making modifications to the plan if needed to preserve air quality. It is hoped that the methods and formats being developed in the Air Pollution-Land-Use Planning Projects--Phase I and II will form a part of this interface package.

4.2.4 Spatial Emission Control via Governmental Inducement Policies-- Indirect Control and Impact Analysis

The control of spatial emission patterns need not take the form of direct, overt, regulatory action on the part of government. Public investment policies or tax incentives are known to affect the location of urban activities. Such policies involve transportation systems, location of public services, land reclamation, etc. Methods for identifying and projecting the existence and spatial extent of potential "hazard" areas are needed so that indirect controls can be applied in time to avoid stoppage of all growth in the area. This problem is especially acute in areas where no comprehensive planning has been undertaken to ensure orderly growth. In these areas, it may be necessary for the state to publicly declare a municipality, county, or region an environmentally depressed area and intensely review all requests for expansion in terms of potential environmental impact.

Possible methods of control in such a case include imposing locational development taxes, withholding funds, withholding public investments, etc. Methods for both identifying local areas that could be subject to future severe environmental degradation due to development and for assessing the impact of fiscal control techniques to meet a particular situation should be at the disposal of state control agencies. Such methods, and possible guidelines for their use, will be investigated during the Phase II project.

4.3 Conclusions

This section has discussed the possibilities for air pollution control related to land use and the spatial distribution of emission patterns. Methods of direct regulation or indirect controls that alter either the expected emission levels from a particular land-use class or the amount of land devoted to a particular use can be used to achieve air quality standards.

It should be emphasized that in this section and throughout this document our goal is to develop methods for dealing with uncertain effects due to uncertain regional growth patterns. It has been assumed that the reduction in this uncertainty is desirable for the planning and enforcement of air pollution controls. Viewed from a control standpoint only, the most desirable situation is one where the air quality has been controlled to the extent that no future uncertainty exists.

Methods suggested here involve using emission density limits as growth guidelines coupled with the more traditional point source regulations. Without the use of density limitations as guidelines, the variance in future emissions can be quite large and alternative methods for evaluating the future land-use plans, coupled with point source regulations, must rely on expected value methods or incorporate uncertainty into the analysis.

In cases where air quality cannot be predicted at all, responsive localized control measures must be available to control agencies. One method suggested was the definition and declaration of local environmentally depressed areas of a region. Temporary closing of such regions to further growth, delay of public funds and investments, and location taxes are some indirect controls available to the control agencies, although guidelines as to the appropriate use and impacts of such measures are needed.

5. ADMINISTRATIVE MECHANISMS OF LOCATIONAL AIR POLLUTION CONTROL POLICIES

5.1 Introduction

The preceding section outlined the range of locational control policies that can be used to distribute emissions throughout a region. This section attempts to place these control strategies in perspective and evaluate them from an administrative point of view.

In the most general context, when economic development fails to account for damaging external effects, as in the case of air pollution, the government has three options to correct such situations: 1) tax or subsidy measures; 2) public investment programs; or 3) legislative/regulatory systems. In the main, implementation plan guidelines have up to now oriented the states toward the regulatory method; but the lack of feasible control technology which can be specified by regulations for some pollutants has caused a shift in this emphasis toward taxation and land-use control. Since it is probable that future air quality control administration will utilize all three methods, the information requirements, administrative staff, institutional interaction, and impact of these administrative systems are discussed for each method in this section.

5.2 Locational Taxation and/or Subsidization

Locational tax programs can be used to discourage growth in areas of high emission rates and poor air quality. Also, accelerated depreciation allowances for high emission producing equipment may be used to encourage replacement of such equipment or the retirement of obsolete facilities. Each of these mechanisms is mainly "responsive" in the sense that they can be employed on short notice once an environmentally depressed area has been identified and declared as such. Thus, such measures are corrective rather than preventive in that they are usually (though not necessarily) applied after environmental degradation has occurred. The converse to such a locational tax is a locational subsidy--a tax break to encourage location in relatively "clean" areas designated for industrial use.

Taxing mechanisms are attractive in that they are adaptive and easy to administer on a short-term horizon through institutional procedures already in operation. Developing a tax schedule for air pollution purposes, however, is not an easy task. The environmental impacts of taxes are not easy to predict and highly uncertain as are the economic impacts. Methods for making these assessments are needed as well as guidelines for employing the tax method before taxation becomes a viable administrative control mechanism.

5.3 Public Investment Programs

Whereas taxation and subsidization schedules attempt to influence locational decisions directly, public investment programs influence behavior indirectly through affecting the supply of public services used by firms. For example, postponing or cancelling public works projects such as transportation systems or sewage treatment facilities in environmentally depressed areas will have a long-term effect on the emissions in the area through reduced economic activity. Conversely, undertaking such projects in clean areas will promote growth and thus increased emissions that otherwise might occur in saturated areas.

Methods for incorporating environmental considerations in public investment planning are needed. Argonne, together with the Chicago Area Transportation Study (CATS) group, has begun a program under State of Illinois auspices to include air pollution and noise impacts in transportation systems planning procedures. The components of this program are shown in Fig. 5.1. Depending on the location and timing of proposed transport systems, air pollution impact analysis may change the staging of the project.

Fig. 5.1. Phase 1 and Phase 2 Systems for Evaluating the Environmental Impact of Alternate Transportation Networks

Since transportation systems and other public works projects typically require a long time-horizon to impact, the final effect of such programs is highly uncertain. Thus, growth in areas due to new public works

projects should be projected forward in time to assess whether or not the resulting growth may lead to an environmentally depressed area. Growth projections of this sort involve locational land-use models that have yet to receive a wide degree of acceptance. Nevertheless, some projections of this type need to be made and environmental considerations should be incorporated in public investment planning.

5.4 Direct Regulation--Responsive Approach

In contrast to the above mechanisms that attempt to influence the forces affecting growth, the current most popular approach to implementing a state air pollution control program is to enact a set of point source control regulations and empower the state control agency to enforce these laws to the best of its ability and budget. The rationale for adopting this approach is that indirect methods are too slow and uncertain and work through market mechanisms that produced environmental problems in the first place. The implementation planning guidelines as set forth by the Federal EPA require the state agencies to have the legal authority to:

"...prevent construction, modification or operation of any stationary source at any location where emissions from such sources will prevent the attainment or maintenance of a national standard.

"...procedures shall provide for the submission by the owner or operator of a new stationary source, or existing source which is to be modified, of such information on the nature and amount of emissions, location, design, construction, and operation of such sources as may be necessary to permit the State agency to make the determination referred to (above)."⁹

This approach is a responsive approach in the sense that environmental regulatory action may not take place until economic pressures have culminated in an expansionary push that endangers environmental quality. The state or local control agency, upon declaring a locality environmentally depressed, becomes a police force bringing to bear whatever measures are reasonable and necessary to prevent further degradation. When the situation is such that these measures become necessary, however, the economic impact on the locality may be quite dramatic and meet with strong resistive pressures.

This approach requires that the state agency acquire a significant administrative and enforcement staff. Since monitoring and permit systems are required to keep informed of localized growth patterns, the extent of the environmental impact of the region is virtually certain, but the economic consequences of such a system remain to be determined. The time required for the program to have effect depends on how efficiently the administrative system can be made to work, but is probably shorter than indirect methods.

5.5 Direct Control--Planned Approach via Zoning

In contrast to the responsive approach of direct control, environmental considerations can be inserted directly into a comprehensive land-use planning process so that environmental degradation is not allowed to occur. In effect, a comprehensive land-use plan and the resulting zoning ordinance used to implement the plan place restrictions on the use of land in order to achieve community goals such as environmental quality, land value stability, compatible uses, etc. Land zoning has had a long history as a method for separating uses that may have external nuisance effects. In recent years, private exploitation of limited natural resources has brought forth a public outcry for more comprehensive long-range planning and methods for conserving these resources.

In the administration of a land-use planning approach, the state agency would probably assume a more passive role than that discussed under the regulatory type of control. The onus of producing a land-use plan and zoning ordinance must reside at the local level since the plan reflects community development objectives. A state planning and zoning agency could provide assistance to local agencies in developing their plans. The State Air Pollution Control Agency would be required to provide counsel to local governments on air pollution matters and ensure interjurisdictional consistency of plans in achieving the overall air quality standards. It would also be responsible for monitoring the development of regions in an indirect sense, but enforcement would mainly proceed through local zoning boards and agencies. Thus, the state agency would act as an umbrella organization, achieving its goals through intergovernmental cooperation at the local level.

In the State of Illinois it has been proposed¹⁰ that a comprehensive State Land-use Code in which counties and municipalities are authorized and encouraged to use zoning ordinances as a method of implementing a comprehensive land-use plan be adopted. Such plans are to be submitted for adoption within five years and reviewed every five years thereafter. Summary reports of local land-use and development actions are to be produced on a yearly basis. It should be a relatively small operation within the state agency to provide an air pollution impact analysis of such plans. Once approved and adopted and enforced, these plans provide insurance that environmental quality will be preserved.

The economic tradeoffs that are made as a result of planned development are difficult to assess. Land set aside for industrial development may never be developed because the planner misjudged the potential of the land. Economic impacts of zoning need further study, but it is obvious that, although the indirect zoning methods could be used to implement a comprehensive plan, zoning has achieved a large degree of popularity.

The planning approach to incorporating air pollution considerations into the design of local development plans is appealing because it avoids the shock of direct regulatory controls to environmentally depressed regions and would seem to require a smaller consulting, rather than enforcement, oriented staff on the state level. Whether comprehensive planning will receive the widespread popularity its supporters believe it should have and whether the degree of governmental cooperation necessary to implement this approach can be achieved remain open questions.

5.6 Conclusions

This section has reviewed various methods for implementing locational control policies. They run the gamut from very indirect to very direct measures. In general, it may be said that indirect measures are least expensive to invoke and enforce but most uncertain as to when or whether desired results are achieved. Direct measures in general require a large staff and thus are costly to administer but at least superficially remove the uncertainties in achieving results.

A second classification of methods is whether the administrative system involves development planning or whether the administration is geared to responding to an existing situation. Response controls require that the criteria for defining and declaring an environmentally depressed area be carefully worked out, because such a declaration itself will carry with it connotations which will have definite impacts on the region involved. Also, the types of control mechanisms to be applied to such areas and guidelines for their use must be fully planned.

Each of the types of methods discussed may, of course, be applied in various combinations if appropriate. Table 5.1 is intended to summarize the discussions of this section. It is hoped that this discussion has captured the major options in implementing control strategies and can provide a framework and directions for further investigations in this area.

TABLE 5.1. Summary of Administrative Techniques for Implementing Locational Air Pollution Control Policies

Eval Criteria:		Cost as Reflected by							
Administration Method	Staff Size	Information Requirements Including		Socioeconomic Impact (degree of certainty, expected time horizon to impact)	Environmental Impacts (degree of certainty, expected time horizon to impact)	Enforcement Role of APCA (active) (passive)	Degree of Interagency Cooperation Required		
		1) Data Collection and Reporting	2) Projection Methods					Staff Competence Required	
Taxation Subsidization Measures	Relatively small	Small	Economic projections of impacts of taxation on location	High	Recommend tax schedules, funds expenditure programs, etc.	Extent of impact uncertain; time horizon short-medium	Extent of impact uncertain; time horizon relatively short-medium	Passive	Taxing bodies, collection agencies
Public Investment Programs	Relatively small	Medium	Growth projection methods, land-use transportation models, interface with dispersion models	Medium High	Analyze impacts of proposed public projects	Extent of impact uncertain; time horizon relatively long	Extent of impact uncertain; time horizon relatively long	Passive	Investment planning agencies, political bodies
Direct Regulation--Responsive Approach	Relatively large	Relatively Large	Surveillance system, permit system, reporting systems	Medium	Control engineering, inspections	Impact uncertain, time horizon short	Impact certain, time horizon short	State active, Local passive	Relatively little interaction required
Direct Regulation--Planned Approach	Relatively small	Medium	Methods and techniques for analyzing land-use plans	Medium High	Interpret results of impact analysis of land-use plans, consult with local planning agencies; establish guidelines	Impact uncertain, time horizon relatively short-medium	Impact certain if plan enforced, time horizon short	State passive, Local active	Local planning and zoning commission, zoning officials, state land-use commission

APPENDIX A

Zoning Survey--Procedure and Application*

(A. S. Cohen)

A.1 Discussion

The intended uses of land are reflected in the various zoning ordinances throughout the region. It is therefore necessary to develop a scheme for evaluating zoning before such regulations can be developed and evaluated. This section will outline the procedures for gathering and processing zoning inventories.

A zoning inventory or survey is defined as the percentage of each areal source unit throughout the region zoned for a given number of intended uses. The data-collection and analytic procedures for obtaining a zoning inventory are presented in Sections A.2 and A.3, respectively. The output of a zoning survey conducted for the Northeastern Illinois Metropolitan Area (NIMA) is given in Section A.4. The NIMA region is defined as the six Illinois counties contained in the Metropolitan Chicago Air Quality Control Region as shown in Fig. A.1.

A.2 Data Collection

A.2.1 Data Requirements

The primary data for conducting a zoning survey are zoning maps and zoning ordinances. In addition, a large map of the study region with clearly defined landmarks (roads, rivers, and county and municipality boundaries) is an essential aid.

Zoning maps can be found in many forms. Some of these are listed below in decreasing order of usefulness:

1. Composite zoning map of the entire region (unincorporated and incorporated areas).
2. Composite zoning map of county (unincorporated and incorporated areas).

*The concept of a zoning survey was formulated during the Chicago Air Pollution Systems Analysis Program. The development of techniques for acquisition of zoning data and their subsequent application were conducted under Contract 31-109-38-2464 between Argonne National Laboratory and the State of Illinois.

Fig. A.1. The Metropolitan Chicago Air Quality Control Region. ANL Neg. No. 190-1.

3. Composite zoning map of unincorporated areas of county.
4. Township zoning map of unincorporated areas.
5. Nonreproduced township zoning map of unincorporated areas.
6. Municipality zoning map.
7. Nonreproduced municipality zoning map.
8. No zoning map.

For the zoning survey conducted in the Northeastern Illinois Metropolitan Area (NIMA), each of these types of maps was used.

A.2.2 Sources of Data

Composite zoning maps are usually developed for planning purposes. Therefore, the major source of these maps would be planning commissions or boards. If a composite map is not available, then the planning group may have a complete or partial file of municipality zoning ordinances and maps. It is obviously desirable to find data sources, such as local or regional planning agencies, that have compiled much of the information sought. The only caution concerning such sources is the timeliness of the data. Often the data files are not updated.

For the NIMA study, a composite zoning map for the entire region was available from the Northeastern Illinois Planning Commission (NIPC). Since the map was made in 1964, it was not used to develop the 1970 zoning inventory. It was used, however, to compare zoning in 1964 to that in 1970. This comparison is discussed in Section A.4.

In addition, a partial file of the municipality zoning maps was available from NIPC. Since the study area for the NIMA analysis coincided with the NIPC study area, a large study-area map was provided from this source.

A 1970 composite zoning map for McHenry County was available for use from the county's planning group. One day was required to analyze all of McHenry County using this map. Similarly, a 1970 composite map of unincorporated areas in Kane County was used.

Township zoning maps of unincorporated areas are usually available from county zoning departments. For the six counties in the NIMA study area, three of them (Cook, Du Page, and Lake) had reproduced maps. The other three (McHenry, Kane, and Will) had nonreproduced township maps. Since composite maps for McHenry and Kane Counties were available, the township maps were not needed. A survey of Will County government records was required to develop the zoning inventory for the unincorporated areas of that county.

The county zoning board also represents a possible source for municipality zoning material. Sometimes each municipality is required to file a local zoning map with the county government.

For incorporated areas, the zoning maps must be obtained directly from the municipalities or from one of the two sources given above.

A.2.3 Recommended Data-acquisition Procedure

Section A.2.1 suggests that there is a hierarchy of data types. For example, updated composite maps are preferred to any other type of data, and composite maps of unincorporated areas are preferred to township maps of unincorporated areas, provided the latter data type is not reproduced. If township maps are reproduced in such a way that municipal zoning can be transferred onto the maps, then this is preferred to a composite map of unincorporated areas. This is because the township maps, plus the added municipality zoning, represent a composite map of the entire area, and this is preferred to a composite map of only the unincorporated areas. This hierarchy suggests that a systematic data-acquisition procedure would greatly reduce the cost and effort of the data-gathering activity.

The first step is to survey the planning groups and county zoning boards to determine the types of data available from these sources. It should be noted what areas have composite maps.* A list of the municipalities in areas for which composite maps are not available is then generated. A list of the municipalities in each county is usually available from the county office or a planning group. These lists should be checked against the municipality zoning-material files of the secondary sources, i.e., planning commissions and county zoning boards.

Those municipalities not having zoning material on file with any secondary source should be contacted to obtain copies of their zoning ordinances and maps. However, when township maps are not reproduced, it is recommended that the municipal zoning material be obtained for this area, even if copies are on file with other sources. This additional copy will allow the analyst to color-code and grid the map to simplify the analysis.

For the NIMA study, the following procedure was used to obtain municipal zoning information. A form letter (see Fig. A.2) was sent to each municipality from which zoning material was desired. A second list of "important" municipalities was developed. Important municipalities were those known to have heavy industry. After two weeks,** all important municipalities that did not respond were telephoned. If copies of their maps were

*A map having both unincorporated and incorporated areas zoned is called a composite map unless otherwise specified.

**Ten working days.

not available and a verbal description was not practical, a personal visit was planned. All personal visits were made on the same day. During the personal visit, a street map or township map was used to outline areas of interest.

Dear Sir:

The Center for Environmental Studies at Argonne National Laboratory has recently initiated a project to develop an implementation plan for the abatement and control of air pollution. Part of this study involves the compilation of zoning maps for Cook, Du Page, Kane, Lake, McHenry, and Will Counties.

The County's Departments of Building and Zoning have already provided the zoning maps and ordinances for the unincorporated areas of this region. Since it is impractical to visit personally all the cities, towns, and villages not zoned by the County, I am asking you to send me a recent copy of your area's zoning ordinances and map(s). Your cooperation in this matter will be greatly appreciated.

Sincerely,

Fig. A.2. Sample Form Letter

Two hundred thirty-five out of 254 municipalities were contacted during the NIMA study. Because of the availability of a composite map in McHenry County, no inquiries were sent to municipalities in the county. The remaining municipalities were all contacted regardless of the availability of zoning material from secondary sources. This was done to compile the statistics given in Tables A.1-A.3. A response to the form letter is defined as a return letter. This letter may be the requested material, a payment requisition, or a statement that the material is not available. A response to a phone call is defined as the receipt of the material or a verbal statement that the material is not available. The response time represents the number of working days from the phone call to the response. Therefore, the total time required to receive the material is 10 days plus the phone-call response time.

TABLE A.1. Reply Times for Municipalities

Number of working days	<10	$10 \leq D \leq 20$	>20	No reply
Letter	74	38	16	61
Phone	27	0	0	14
Personal visit	5 municipalities were visited			

Where maps are not reproduced, an attempt should be made to obtain a verbal description of the zoning over the phone. As with a personal visit, a street or township map can be used to verbally describe the important boundaries.

TABLE A.2. Data Sources for Municipality Maps

Source Type	Municipalities	Secondary Source	Composite Map	Total Maps Used	No Data	Total Municipalities
Number supplied	155	26	19	200	54	254
Percent	60	10	8	78	22	100

TABLE A.3. Survey Costs

Analyst cost	\$3,000
Secretarial service	350
Computer programming and related cost	650
Mailing cost	30
Travel cost	110
Purchase cost ^a	60
Total cost	\$4,200

^aOf the 235 municipalities contacted, only 13 requested remittance for the zoning material.

While waiting for municipality zoning material to arrive, the analyst can perform some of the analysis. Composite maps can be analyzed during the waiting period. In addition, township maps can be collected and municipal zoning transferred to the map from information available from secondary sources. If township maps are not reproduced, then unincorporated composite maps or non-reproduced township maps can be analyzed.

The McHenry County composite map, the Kane County unincorporated composite map, and the Will County nonreproduced township maps were analyzed during the waiting period. In addition, the Cook, Lake, and Du Page County township maps were gradually transformed to composite maps as the information arrived. The analytic procedure is designed in such a way that additional information can be used if it arrives after the analysis has been completed. Therefore, the analysis can be conducted for any section if most (70-80%) of the information is in hand. For the NIMA study, 78% of the municipalities in the six-county region had their zoning included in the analysis. The 22% not responding were considered unimportant for the study. If, however, they send in their zoning maps and ordinances the information can readily be added to the results.

A.3 The Analysis

A.3.1 Zoning Classifications

Two important decisions must be made concerning zoning classifications. First of all, the number of zoning classes to be considered must be determined. For example, eight zoning categories were used in a zoning survey of Chicago. They are: single-family residential, multifamily residential, business, commercial, limited manufacturing, general manufacturing, heavy manufacturing, and others. In contrast, the NIMA study used only four classes: limited, general, and heavy manufacturing, and other.

It is theoretically pleasing to consider as many zoning categories as possible. Practically speaking, however, each additional classification increases the number of grids to be analyzed. In addition, the time required to analyze each grid is increased. For the Chicago inventory, 247 square miles were analyzed. Conservatively estimating a 5-min average for each grid gives a total of 20.5 hr of analysis. Assuming the same average time per grid for the 4800 square miles in the NIMA region, the analysis would have taken approximately 400 hr or 2.4 man-months.

In addition to this increased time for analysis, the time for data collection and processing would increase. Since the total NIMA survey from start to finish was less than 2 man-months and the subsequent usefulness of the inventory was not substantially reduced, considerable time and money were saved by reducing the number of zoning classes.

The second task to be conducted is the development of standard definitions of zoning classes to be analyzed. The term "general manufacturing" may be used by many municipalities or counties in their zoning ordinances, but the use of the term will vary. Rather than forming strict definitions for each class, guidelines should be developed. A strict definition may not fit some of the municipality classifications. Table A.4 represents a sample guideline for manufacturing classes. Many municipalities will have business districts that allow industrial-processing activities. For the zoning survey, these districts would most likely be called M1 districts. Similarly, a manufacturing district that allows food processing, but not the other exceptions, may still be classified as an M1 district. The assignment of zoning classes is a responsibility of the analyst. The guidelines will help make this task uniform.

TABLE A.4. Guidelines for Industrial Classifications

M1	<u>Limited Manufacturing District</u>
	Must have provision for assembly, processing, fabrication, and storage plants. No raw materials shall be processed into any of the following basic products: metals of any kind, glass, plastics, textiles, leather, paper, petroleum, chemicals, or food.
	Also, no municipal incineration or motor-freight terminals are allowed in M1 districts.
M2	<u>General Manufacturing District</u>
	Has same restrictions as M1, but allows for municipal incineration and motor-freight terminals.
M3	<u>Heavy Manufacturing District</u>
	No restrictions.

One difficulty may arise while classifying manufacturing districts. Often a stone or sand quarry and strip mine are classified as heavy manufacturing, and no distinction is made on the zoning map. If it is desirable to create a new class for these types of sources, additional information is needed to determine what sections of the region are quarries or mines. The number of zoning classes and their definitions are a function of the intended use of the inventory. For air-pollution control, the manufacturing classes and definitions given may suffice. However, this inventory would have little use for a housing study.

A.3.2 Areal Unit Systems

To conduct a zoning survey, any type of areal unit can be used. Since the results of a zoning survey show the percentage of each areal unit zoned for a particular use, the areal units need not be uniform or even have regular shapes.

Three possible areal-unit systems are discussed below in terms of the ease of conducting the survey, the accuracy of the results, and the usefulness of the inventory. The usefulness of the zoning survey is defined in this context as its applicability to an atmospheric-dispersion model.

The first areal system uses municipal and township boundaries as units. The primary advantage of this system is that municipality and township maps would by definition represent the areas to be analyzed. This greatly simplifies the analysis. Furthermore, the number of units to consider is relatively small. For example, if these units were used rather than square miles, the number of units analyzed for the NIMA survey would have been reduced by 75%. Since fewer units are considered for the same total area, it is possible to easily increase the accuracy of the zoning inventory. This procedure is discussed in detail in Section A.3.3.

Since the areal units are irregular in shape, analytical use of the results is prohibitively difficult. This inventory can be converted into one using regular areal units, i.e., a grid system. The zoning need only be proportionally assigned to the grids that are superimposed over each areal unit. However, this procedure assumes uniformity of zoning throughout each municipality and township. This greatly reduces the accuracy of the results. Furthermore, "hot spots" (areas zoned for heavy industry) could not be identified. For example, if Chicago were considered a single source for a zoning inventory, it would show that 7% of Chicago's 247-square-mile area is zoned for heavy industry. To make this result useful in a dispersion model, assume a square-mile grid is used. Therefore, 7% of each grid is assumed to be zoned for heavy industry. (Actually, heavy industrial zoning ranges from 0 to 89% in Chicago.)

The difficulties encountered using the municipality and township boundaries as areal units can be eliminated by using a rectangular or polar grid system. As the size of the grids decreases, the time for analysis increases. A uniform grid size is not necessary; however, as the grids get larger, the ability to locate "hot spots" decreases. Therefore, the size of the grids used must be determined based on the relative values of cost and time versus accuracy of resolution. It may be advantageous to use the grid system used in the development of an emission inventory. This would allow correlation studies between zoning and emissions.

Two disadvantages are associated with a superimposed grid areal system. First, this approach is more expensive than the political-boundary system discussed above. Since the grid system does not necessarily follow

any natural boundaries, the grid must be superimposed onto every map analyzed. (A transparent overlay is helpful when many maps analyzed have the same scale.) Considerable time is spent to align the grid properly on the many maps that need to be analyzed. Often this procedure takes more time than the analysis. The large map of the study region is a great aid for finding the coordinates of landmarks that can easily be found on the municipality or township maps.

Because grid alignment is necessary when using a regular areal system, another source of error is introduced into the analysis. In addition to the obvious errors resulting from map-scale errors and transfer errors, there are errors of aggregation. Assume township maps are not reproduced, and the inventory for the unincorporated areas must be done separately from the municipality survey. The grids that cross municipality boundaries will be analyzed more than once. Therefore, it becomes possible for a grid to be assigned more than 100% zoned for industry when the individual results are aggregated.

These errors are not very critical. With care in aligning grids, errors of less than a quarter of a mile can be obtained. With appropriate allocation schemes during aggregation, some difficulties can be corrected.

A third approach, which may not be as general as the above but has all the advantages and fewer disadvantages associated with it, uses sectional boundaries as areal units. These boundaries are marked on township and municipality maps. In addition, these are small and regular enough to avoid the problems encountered in the municipality-township-boundary approach. Such a system exists for the NIMA region. This areal system is shown in Fig. A.3, where most of the units are square miles. In fact, in Chicago the square-mile grid system and the sectional system coincide.

Although the third approach is preferred over the other two approaches, it was not used for the NIMA survey because the square-mile grid system can be easily converted to the grid system used for an emission inventory. Furthermore, one objective of the NIMA study is to develop a general approach for generating a zoning survey and to determine the difficulties involved. This could not be done using the sectional-boundary approach.

A.3.3 A Modified Monte Carlo Procedure for Conducting a Zoning Survey

The output of a zoning survey is the percentage of land zoned in each areal unit for a given number of specified zoning classes. For a few grids, it may be practical to use a planimeter; however, for large areas, e.g., the Chicago air quality region, a quick but accurate method to analyze each grid

Fig. A.3

Northeastern Illinois Metropolitan
Area. ANL Neg. No. 190-3.

is required. A modified Monte Carlo procedure used in many land-use surveys (see Hadfield, 1966) provides an appropriate approach for conducting a zoning survey.

To determine the percentage of a given land area zoned for manufacturing, the Monte Carlo procedure would generate a set number of random points, N , which would fall into the area being studied. If p of these points fall onto land zoned for manufacturing, then $(p/N)(100)$ is the percentage of the total area zoned for manufacturing. With a confidence level of 0.66, the actual percent area zoned for manufacturing is calculated as $(p/N)(100) + \sigma_p$, where

$$\sigma_p = \sqrt{pq/N} \text{ and } q = N - p.$$

For example, assume $N = 100$ and $p = 45$, then 45% of the land is zoned for industry and 55% is zoned otherwise. These figures, in all probability, are within ± 5 of the actual values,

$$4.97 = \sqrt{(45)(55)/100}.$$

The modified Monte Carlo procedure does not use a randomly generated set of points, but rather a "stratified systematic unaligned" set of points (see Fig. A.4). As defined in Hadfield,¹¹

"A stratified systematic unaligned pattern is produced as follows: a plane surface is divided into squares of equal size which constitute strata. First, a point is placed in each square in the left-hand column of squares, all points having the same Y coordinate within each square (the first Y coordinate is chosen at random) but different X coordinates, each chosen at random... . Second, points are similarly placed in the bottom row of squares, this time using a constant X coordinate but different Y 's for each square. Finally, points are placed in the remainder of the square, each point taking its X coordinate from the left-hand column in the same row and its Y from the bottom row in the same column of squares. The construction and benefits of such a pattern are further described by B. J. L. Berry." (See Berry.¹²)

The modified approach has empirically generated smaller errors than the calculated error from the random approach. Table A.5 compares the results of this approach and a lengthy "eyeball" approach used to obtain a zoning inventory for Chicago. Assuming the lengthy approach to be the actual value, we see that the actual "error" is indeed less than the calculated error. An example of one of these grids is given in Figs. A.5 and A.6.

Fig. A.4
Stratified Systematic Un-
aligned Array of Dots

TABLE A.5. Actual vs Calculated Errors Using
the Modified Monte Carlo Procedure

	Grid	M1	M2	M3	Other
Calculated		18	17	0	65
"Actual"	108B	18	15	0	67
Calculated error		± 3.8	± 3.8	-	± 4.8
Actual error		0	+2	0	-2
Calculated		8	28	23	31
"Actual"	115B	8	28	24	30
Calculated error		± 2.7	± 4.5	± 4.2	+1
Actual error		0	0	-1	+1
Calculated		0	17	0	83
"Actual"	24B	2	17	0	81
Calculated error		-	± 3.8	-	± 3.8
Actual error		-2	0	0	+2

RESIDENCE DISTRICTS

- R1 SINGLE-FAMILY RESIDENCE DISTRICT
- R2 SINGLE-FAMILY RESIDENCE DISTRICT
- R3 GENERAL RESIDENCE DISTRICT
- R4 GENERAL RESIDENCE DISTRICT
- R5 GENERAL RESIDENCE DISTRICT
- R6 GENERAL RESIDENCE DISTRICT
- R7 GENERAL RESIDENCE DISTRICT
- R8 GENERAL RESIDENCE DISTRICT

BUSINESS DISTRICTS

- B1-1 TO B1-5 LOCAL RETAIL DISTRICTS
- B2-1 TO B2-5 RESTRICTED RETAIL DISTRICTS
- B3-1 TO B3-5 GENERAL RETAIL DISTRICTS
- B4-1 TO B4-5 RESTRICTED SERVICE DISTRICTS
- B5-1 TO B5-5 GENERAL SERVICE DISTRICTS
- B6-6 AND B6-7 RESTRICTED CENTRAL BUSINESS DISTRICTS
- B7-5 TO B7-7 GENERAL CENTRAL BUSINESS DISTRICTS

COMMERCIAL DISTRICTS

- C1-1 TO C1-5 RESTRICTED COMMERCIAL DISTRICTS
- C2-1 TO C2-5 GENERAL COMMERCIAL DISTRICTS
- C3-1 TO C3-7 COMMERCIAL-MANUFACTURING DISTRICTS
- C4 MOTOR FREIGHT TERMINAL DISTRICT

MANUFACTURING DISTRICTS

- M1-1 TO M1-5 RESTRICTED MANUFACTURING DISTRICTS
- M2-1 TO M2-5 GENERAL MANUFACTURING DISTRICTS
- M3-1 TO M3-5 HEAVY MANUFACTURING DISTRICT

Fig. A.5

Square Mile Zoned in Chicago.
ANL Neg. No. 190-4 Rev. 1.

Using this approach, we can analyze a single grid in less than a minute. It has the advantage of limiting the subjective judgment of the analyst which is prevalent in an eyeball approach. A point will usually fall into a zoning category or not. An arbitrary rule for borderline cases will eliminate any bias from the analyst. Furthermore, this technique can be performed by a technician, since no special training is required.

A.3.4 Data Aggregation

The output of a zoning inventory can be represented as paired vectors. The first vector identifies the source, and the second delineates the percentage of the source zoned for each use surveyed. For example, a typical output from the NIMA study is (10, 43), (1, 12, 6), where the first vector represents the x-y coordinate of the grid analyzed and the second vector shows the percent of that grid zoned for limited, general, and heavy manufacturing. These paired vectors represent a mapping (function) from grid source to zoning classes. If a composite map of the region is available, this function can be obtained without any aggregation. However, when composite maps are not available, the same source may be analyzed more than once.

This multiple analysis of the same source may occur in different ways. First, the same grid may have to be analyzed separately for unincorporated and incorporated areas. This would occur if township maps were not reproduced. Second, a superimposed grid system, by definition, does not necessarily follow natural boundaries, and therefore the grid overlay would not fit exactly all the maps analyzed. Thus, more than one map is required to completely analyze a given grid under these circumstances.

It is important to always obtain the percentage of the entire grid that is zoned in each class, even if the entire grid does not fit on the map being analyzed. The part of the grid not falling on the map is considered to be zoned "other." In this way, only a simple summation is required to obtain the complete grid analysis. Similarly, data missing during the survey can be easily added when obtained by this summation process.

As mentioned earlier, the summation process may result in some grids being zoned for more than 100% of the grid. This may result from the statistical procedure used or from grid-alignment errors. There are many ways to correct this obvious type of error. One is to proportionally reduce each zoning class in the grid to make the total equal to 100%. This was done for those grids with industrial zoning listed between 101 and 105% in the NIMA study. It was assumed that in this range the error was statistical. For grids with industrial zoning greater than 105%, the grid and its surrounding area were analyzed a second time. In this way, the excess industrial zoning area is not lost, but reallocated to the adjacent grids. It

is possible to do this reallocation automatically by proportionally allocating the excess industrial zoning to adjacent grids. This procedure is not as accurate as a reexamination of the area, but it is much quicker and can be done on a computer.

Other forms of data manipulation are possible, once the zoning inventory is complete. The original mapping of source to zoning classes can be transferred by aggregating sources or zoning classes to obtain new mappings. For the NIMA survey, the square-mile grid sources were aggregated into a nonuniform grid pattern used for an emission inventory of the region. In addition, the limited- and general-manufacturing classes were combined to obtain a light-manufacturing class. This latter aggregation is done to reduce the dimensionality of subsequent analysis if it is required.

When it is economically justified, data should be collected on small units and with large numbers of classes. This creates more flexibility of use, because the data can be converted easily upward through aggregation. Although conversion to smaller units is possible, some accuracy is usually lost.

A.4 Results

The complete 1970 zoning survey for the NIMA study area is presented below. Four types of aggregation are used and are presented in the order listed here. (See Fig. A.7 and Table A.6 for areal-unit designation.)

1. Areal units of square miles and zoning classes of limited, general, and heavy manufacturing (see Table A.7).
2. Areal units of square miles and zoning class of light and heavy manufacturing (see Table A.8).
3. Areal units of source I.D. and zoning classes of limited, general, and heavy manufacturing (see Table A.9).
4. Areal units of source I.D. and zoning classes of light and heavy manufacturing (see Table A.10).

The output lists the area-source identification and the percent of the source zoned in each class. (M1 = limited manufacturing, M2 = general manufacturing, M1 + M2 = light manufacturing, M3 = heavy manufacturing.) In addition, when source I.D. units are used, the size of the source in square miles is also given.

For the 1970 survey, only one square mile showed an error in aggregation. Since this error was less than 5%, the computer program used to process the raw data automatically reduced each zoning class proportionally.

Fig. A.7. X,Y and I.D. Grid Systems. ANL Neg. No. 190-15.

TABLE A.6. X,Y and I.D. Mapping^a

X	Y	I.D.	X	Y	I.D.	X	Y	I.D.	X	Y	I.D.	X	Y	I.D.
46	51	10	45	51	20	44	51	30	43	51	40	42	51	50
46	50	60	45	50	70	44	50	80	43	50	90	42	50	100
46	49	110	45	49	120	44	49	130	43	49	140	42	49	150
46	48	160	45	48	170	44	48	180	43	48	190	42	48	200
46	47	210	45	47	220	44	47	230	43	47	240	42	47	250
47	46	260	46	46	270	45	46	280	44	46	290	43	46	300
42	46	310	44	54	320	42	54	330	40	54	340	44	52	350
42	52	360	40	52	370	40	50	380	40	48	390	40	46	400
46	44	410	44	44	420	42	44	430	40	44	440	48	42	450
46	42	460	44	42	470	42	42	480	40	42	490	50	39	500
50	37	510	30	87	520	20	87	530	10	87	540	0	87	550
30	77	560	20	77	570	10	77	580	0	77	590	30	67	600
20	67	610	10	67	620	0	67	630	40	61	640	35	62	650
40	62	660	20	57	670	10	57	680	0	57	690	0	57	690
40	56	700	35	57	710	30	57	720	35	52	730	30	52	740
20	47	750	10	47	760	0	47	770	35	47	780	30	47	790
35	42	800	30	42	810	20	42	820	10	42	830	0	42	840
45	37	850	40	37	860	35	37	870	30	37	880	45	32	890
40	32	900	30	27	910	20	27	920	10	27	930	45	27	940
40	27	950	45	22	960	40	22	970	30	17	980	20	17	990
10	17	1000	45	17	1010	40	17	1020	40	7	1030	30	7	1040
20	7	1050	10	7	1060	50	35	1360	50	33	1370	50	31	1380
50	29	1390	50	27	1460	50	22	1550	50	12	1590	50	2	1620

^aThe X,Y coordinate is for the lower left-hand corner of the I.D. grid. Only those grids in Illinois are listed.

TABLE A.7. X,Y Listing of 1970 Data for
Limited, General, and Heavy Manufacturing

X	Y	M1	M2	M3	TOTAL	X	Y	M1	M2	M3	TOTAL	X	Y	M1	M2	M3	TOTAL
0 40	1.	0.	0.	0.	1.	11 45	1.	38.	0.	39.	14 52	34.	46.	0.	0.	0.	80.
0 42	2.	0.	0.	0.	2.	11 47	0.	2.	6.	8.	14 53	48.	0.	0.	0.	0.	48.
0 69	1.	0.	0.	0.	1.	11 48	0.	13.	1.	14.	14 54	18.	0.	0.	0.	0.	18.
0 90	1.	0.	0.	0.	1.	11 49	0.	27.	0.	27.	14 57	36.	0.	0.	0.	0.	36.
1 42	0.	0.	0.	4.	4.	11 52	24.	6.	0.	30.	14 58	1.	10.	30.	41.	41.	
1 46	3.	0.	0.	0.	3.	11 53	12.	0.	0.	12.	14 59	3.	20.	67.	90.	90.	
1 63	0.	0.	1.	1.	1.	11 57	1.	0.	6.	7.	14 60	12.	0.	4.	16.	16.	
1 91	1.	0.	0.	1.	1.	11 58	0.	0.	6.	6.	14 61	1.	0.	0.	0.	1.	
2 44	3.	0.	0.	0.	3.	11 59	9.	0.	21.	30.	14 63	1.	0.	0.	0.	1.	
2 46	1.	0.	0.	0.	1.	11 60	3.	0.	0.	3.	14 73	4.	0.	0.	0.	4.	
2 50	1.	0.	0.	0.	1.	11 61	3.	0.	0.	3.	14 74	10.	0.	0.	0.	10.	
2 51	0.	0.	5.	5.	11 62	21.	0.	17.	38.	14 76	16.	0.	0.	0.	16.		
2 54	1.	0.	0.	1.	1.	11 63	19.	0.	19.	14 82	1.	0.	0.	0.	1.		
2 58	2.	0.	0.	2.	2.	11 64	1.	0.	1.	15 6	0.	0.	2.	2.	2.		
2 64	2.	0.	0.	2.	2.	11 65	0.	0.	2.	15 16	0.	0.	40.	40.	40.		
2 65	4.	0.	0.	4.	4.	11 66	0.	0.	13.	15 17	0.	0.	100.	100.	100.		
3 51	0.	0.	8.	8.	11 67	3.	0.	15.	18.	15 18	0.	0.	61.	61.	61.		
3 61	3.	0.	0.	3.	3.	11 70	16.	0.	16.	15 19	4.	0.	16.	40.	40.		
3 65	3.	0.	0.	3.	3.	11 71	28.	0.	18.	15 20	0.	0.	2.	2.	2.		
3 81	10.	0.	6.	16.	11 72	28.	0.	0.	28.	15 21	0.	0.	4.	4.	4.		
3 82	18.	0.	6.	24.	11 73	36.	0.	0.	36.	15 22	2.	0.	5.	7.	7.		
3 83	16.	0.	0.	16.	11 74	44.	0.	0.	44.	15 24	1.	0.	0.	1.	1.		
4 61	1.	0.	0.	1.	11 75	42.	0.	0.	42.	15 25	7.	0.	0.	7.	7.		
4 69	2.	0.	0.	2.	11 76	9.	0.	0.	9.	15 30	2.	0.	0.	2.	2.		
4 70	1.	0.	0.	1.	11 83	8.	0.	0.	8.	15 31	23.	0.	0.	23.	23.		
4 71	1.	0.	6.	7.	11 91	0.	0.	6.	6.	15 32	26.	0.	0.	26.	26.		
4 79	9.	0.	0.	9.	11 92	8.	0.	10.	18.	15 33	33.	0.	0.	33.	33.		
4 80	2.	0.	0.	2.	11 93	0.	0.	4.	4.	15 36	14.	0.	0.	14.	14.		
4 81	6.	0.	0.	6.	12 41	0.	0.	1.	1.	15 37	2.	0.	0.	2.	2.		
4 91	0.	0.	2.	2.	12 42	8.	0.	29.	37.	15 38	3.	0.	0.	3.	3.		
4 92	4.	0.	0.	4.	12 43	6.	7.	4.	17.	15 42	0.	0.	62.	62.	62.		
4 93	4.	0.	0.	4.	12 44	0.	10.	8.	18.	15 43	12.	0.	24.	36.	36.		
5 50	3.	0.	0.	3.	12 45	19.	8.	17.	43.	15 44	9.	0.	0.	9.	9.		
5 56	2.	0.	0.	2.	12 48	0.	15.	8.	23.	15 45	23.	0.	0.	23.	23.		
5 69	10.	0.	0.	19.	12 49	0.	8.	31.	39.	15 49	22.	0.	0.	22.	22.		
5 70	8.	0.	8.	16.	12 50	2.	0.	0.	2.	15 50	0.	68.	0.	68.	68.		
5 71	1.	0.	0.	1.	12 52	44.	0.	0.	44.	15 51	18.	6.	0.	24.	24.		
5 78	2.	0.	0.	2.	12 53	12.	0.	12.	12.	15 52	6.	26.	0.	32.	32.		
5 79	32.	0.	0.	32.	12 57	8.	0.	40.	48.	15 56	4.	0.	0.	4.	4.		
5 80	37.	0.	0.	37.	12 58	1.	0.	9.	10.	15 57	68.	0.	0.	68.	68.		
5 81	6.	0.	0.	6.	12 59	0.	32.	32.	32.	15 58	0.	14.	0.	14.	14.		
5 84	4.	0.	0.	4.	12 60	13.	0.	8.	21.	15 59	11.	0.	0.	11.	11.		
5 91	6.	0.	3.	9.	12 61	8.	0.	0.	8.	15 60	3.	0.	0.	3.	3.		
5 92	1.	0.	1.	2.	12 62	6.	0.	0.	6.	15 72	8.	0.	0.	8.	8.		
5 93	0.	0.	4.	4.	12 63	4.	0.	0.	4.	15 73	10.	0.	0.	10.	10.		
6 40	0.	17.	12.	29.	12 66	20.	0.	5.	25.	15 88	8.	0.	0.	8.	8.		
6 42	2.	0.	0.	2.	12 67	29.	0.	14.	43.	15 89	6.	0.	1.	7.	7.		
6 48	1.	0.	0.	1.	12 68	1.	0.	19.	20.	16 10	0.	0.	23.	23.	23.		
6 50	4.	0.	0.	4.	12 71	0.	0.	14.	14.	16 11	1.	0.	10.	11.	11.		
6 59	1.	0.	0.	1.	12 73	1.	0.	0.	1.	16 16	0.	0.	20.	20.	20.		
6 69	0.	3.	0.	3.	12 74	22.	0.	0.	22.	16 17	0.	0.	84.	84.	84.		
6 78	8.	0.	0.	8.	12 75	4.	0.	0.	4.	16 18	0.	0.	82.	82.	82.		
6 79	20.	0.	0.	20.	12 77	14.	0.	0.	14.	16 19	5.	0.	23.	28.	28.		
6 91	6.	0.	0.	6.	12 78	2.	0.	0.	2.	16 20	0.	0.	65.	65.	65.		
6 92	1.	0.	0.	1.	12 79	1.	0.	1.	1.	16 21	2.	0.	24.	26.	26.		
7 40	0.	0.	54.	54.	12 80	6.	0.	0.	6.	16 22	7.	0.	3.	10.	10.		
7 62	8.	0.	0.	8.	12 81	8.	0.	2.	10.	16 24	5.	0.	0.	5.	5.		
7 63	3.	0.	2.	5.	12 83	5.	0.	0.	5.	16 25	10.	6.	0.	16.	16.		
7 65	0.	0.	2.	2.	12 85	8.	0.	0.	8.	16 27	7.	0.	0.	7.	7.		
7 66	2.	0.	4.	6.	12 86	1.	0.	0.	1.	16 30	1.	0.	4.	5.	5.		
7 68	0.	0.	1.	1.	12 92	2.	0.	0.	2.	16 31	5.	0.	56.	61.	61.		
7 75	4.	0.	0.	4.	13 3	0.	0.	9.	9.	16 32	20.	0.	40.	60.	60.		
7 97	1.	0.	0.	1.	13 4	0.	0.	47.	47.	16 33	12.	0.	23.	35.	35.		
8 40	1.	7.	63.	71.	13 5	0.	0.	30.	30.	16 34	0.	0.	6.	6.	6.		
8 41	0.	1.	5.	6.	13 6	0.	0.	37.	37.	16 35	0.	0.	2.	2.	2.		
8 44	0.	1.	1.	2.	13 16	0.	0.	2.	2.	16 36	3.	0.	4.	7.	7.		
8 45	0.	0.	19.	19.	13 22	0.	0.	9.	9.	16 42	0.	6.	40.	46.	46.		
8 48	1.	0.	0.	1.	13 42	4.	0.	72.	76.	16 43	16.	0.	10.	26.	26.		
8 50	4.	2.	0.	6.	13 44	0.	0.	42.	42.	16 45	10.	0.	0.	10.	10.		
8 52	0.	0.	0.	0.	13 49	1.	0.	0.	1.	16 52	23.	0.	0.	23.	23.		
8 62	2.	0.	0.	2.	13 57	0.	0.	7.	7.	16 52	8.	0.	0.	8.	8.		
8 66	4.	0.	0.	4.	13 58	25.	30.	1.	56.	16 79	1.	0.	0.	1.	1.		
8 77	4.	0.	0.	4.	13 59	0.	82.	8.	90.	16 81	12.	0.	0.	12.	12.		
9 40	0.	5.	2.	7.	13 60	8.	0.	0.	8.	16 88	9.	0.	0.	9.	9.		
9 41	2.	14.	23.	39.	13 61	6.	0.	0.	6.	17 10	0.	0.	15.	15.	15.		
9 42	5.	1.	15.	21.	13 67	3.	0.	0.	3.	17 11	4.	0.	1.	5.	5.		
9 43	0.	0.	22.	22.	13 63	5.	0.	0.	5.	17 18	0.	0.	9.	9.	9.		
9 44	5.	0.	22.	27.	13 66	5.	0.	0.	5.	17 19	0.	0.	18.	18.	18.		
9 45	0.	13.	18.	28.	13 67	2.	0.	0.	2.	17 20	0.	0.	100.	100.	100.		
9 48	0.	0.	3.	3.	13 69	1.	0.	0.	1.	17 21	0.	0.	97.	97.	97.		
9 49	0.	0.	11.	11.	13 72	6.	0.	0.	6.	17 22	0.	0.	72.	72.	72.		
9 50	0.	0.	28.	28.	13 73	3.	0.	0.	3.	17 23	0.	0.	36.	36.	36.		
9 52	16.	2.	10.	28.	13 74	1.	0.	47.	48.	17 25	0.	1.	1.	2.	2.		
9 53	3.	2.	0.	5.	13 75	0.	0.	14.	14.	17 30	1.	0.	18.	19.	19.		
9 60	24.	0.	0.	24.	13 81	18.	0.	3.	21.	17 31	0.	0.	70.	70.	70.		
9 61	1.	0.	0.	1.	13 82	2.	0.	0.	2.	17 32	0.	0.	59.	59.	59.		
9 67	0.	0.	0.	0.	13 83	14.	0.	0.	14.	17 33	0.	0.	62.	62.	62.		
9 91	0.	0.	2.	2.	13 88	3.	0.	0.	3.	17 34	0.	0.	41.	41.	41.		
10 39	0.	0.	8.	8.	14 3	0.	0.	20.	20.	17 35	0.	0.	3.	3.	3.		
10 40	0.	0.	8.	8.	14 4	0.	0.	80.	80.	17 36	0.	0.	3.	3.	3.		
10 41	2.	1.	0.	3.	14 7	0.	0.	8.	8.	17 43	1.	0.	1.	2.	2.		
10 42	7.	8.	18.	33.	14 11	0.	0.	40.	40.	17 46	0.	0.	1.	1.	1.		
10 43	5.	17.	10.	27.	14 13	1.	0.	0.	1.	17 47	0.	0.	4.	4.	4.		
10 44	1.	14.	6.	21.	14 16	0.	0.	6.	6.	17 52	18.	0.	0.	18.	18.		
10 45	8.	3.	14.	25.	14 17	0.	0.	29.	29.	17 57	12.	0.	0.	12.	12.		
10 47	0.	2.	17.	19.	14 18	0.	0.	7.	7.	17 80	4.	0.	0.	4.	4.		
10 48	0.	3.	10.	13.	14 19	0.	0.	27.	27.	17 87	10.	0.	0.	10.	10.		
10 49	1.	3.	0.	4.	14 20	0.	0.	8.	8.	18 7	1.	0.	0.	1.	1.		
10 50	0.	0.	2.	2.	14 21	9.	0.	4.	13.	18 13	5.	0.	0.	5.	5.		
10 52	6.	0.	0.	6.	14 22	1.	0.	10.	11.	18 14	0.	0.	16.	16.	16.		
10 53	6.	0.	0.	6.	14 25	5.	0.	0.	5.	18 19	0.	0.	5.	5.	5.		
10 57	3.	0.	4.	7.	14 29	0.	0.	3.	3.	18 20	0.	0.	10.	10.	10.		
10 58	0.	0.	4.	4.	14 30	0.	0.	10.	10.	18 21	0.	0.	10.	10.	10.		
10 59	0.	0.	6.	6.	14 31	8.	0.	0.	8.	18 22	0.	0.	43.	43.	43.		
10 60	37.	0.	0.	37.													

TABLE A.7 (Contd.)

X	Y	M1	M2	M3	TOTAL	X	Y	M1	M2	M3	TOTAL	X	Y	M1	M2	M3	TOTAL
19	7	1.	0.	4.	5.	24	26	9.	0.	0.	9.	30	39	11.	5.	0.	16.
19	8	0.	0.	8.	8.	24	34	0.	0.	53.	53.	30	52	12.	0.	0.	12.
19	22	0.	0.	5.	5.	24	35	6.	0.	59.	65.	30	53	8.	7.	0.	15.
19	23	0.	0.	68.	68.	24	36	17.	0.	27.	44.	30	54	0.	20.	0.	20.
19	24	0.	0.	68.	68.	24	37	41.	0.	41.	41.	30	55	48.	22.	3.	73.
19	25	6.	0.	6.	6.	24	38	5.	0.	0.	5.	30	56	21.	0.	0.	21.
19	27	0.	1.	0.	1.	24	44	38.	0.	38.	38.	30	58	4.	28.	0.	32.
19	28	3.	2.	0.	5.	24	46	16.	0.	0.	16.	30	59	62.	9.	9.	80.
19	32	0.	0.	3.	3.	24	50	10.	0.	0.	10.	30	67	2.	0.	0.	2.
19	33	0.	0.	44.	44.	24	51	6.	0.	0.	6.	30	68	12.	0.	0.	12.
19	43	2.	5.	0.	7.	24	52	6.	0.	0.	6.	30	69	2.	0.	0.	2.
19	51	19.	0.	0.	19.	24	53	20.	0.	0.	20.	30	70	18.	0.	0.	18.
19	52	1.	0.	0.	1.	24	55	6.	0.	0.	6.	30	71	6.	0.	0.	6.
19	54	32.	0.	0.	32.	24	56	5.	0.	0.	5.	30	72	22.	0.	0.	22.
19	55	10.	0.	0.	10.	24	57	12.	0.	0.	12.	30	78	15.	0.	0.	15.
19	57	25.	0.	0.	25.	24	61	17.	0.	0.	17.	31	15	1.	0.	0.	1.
19	58	4.	0.	0.	4.	24	62	60.	0.	0.	60.	31	39	4.	38.	0.	42.
19	63	27.	0.	0.	27.	24	63	4.	0.	0.	4.	31	49	5.	0.	0.	5.
19	77	7.	0.	0.	7.	24	64	25.	0.	0.	25.	31	51	0.	48.	16.	64.
19	78	0.	0.	0.	0.	24	65	5.	0.	0.	5.	31	53	6.	54.	0.	60.
20	23	0.	0.	34.	34.	24	66	5.	0.	0.	5.	31	54	5.	45.	0.	50.
20	24	1.	2.	16.	19.	24	73	20.	0.	0.	20.	31	55	1.	71.	11.	83.
20	28	2.	28.	0.	30.	24	85	12.	0.	0.	12.	31	58	18.	1.	0.	19.
20	38	4.	0.	0.	4.	25	32	4.	0.	0.	4.	31	59	16.	2.	0.	18.
20	43	18.	0.	0.	18.	25	34	0.	0.	0.	0.	31	65	2.	56.	0.	58.
20	44	0.	0.	1.	1.	25	35	0.	0.	11.	11.	31	66	20.	25.	0.	49.
20	48	0.	0.	8.	8.	25	36	12.	0.	71.	83.	31	67	34.	15.	0.	44.
20	49	0.	0.	20.	20.	MFAF (M1+M2+M3) BETWFA 100 AND 105											
20	50	3.	0.	0.	3.	25	37	100.	0.	0.	100.	31	69	4.	0.	0.	13.
20	51	53.	0.	0.	53.	25	38	16.	0.	0.	16.	31	72	21.	0.	0.	21.
20	52	58.	0.	0.	58.	25	45	5.	0.	0.	5.	31	77	14.	0.	0.	14.
20	53	26.	0.	0.	26.	25	46	22.	0.	0.	22.	31	88	10.	0.	0.	10.
20	54	44.	0.	0.	44.	25	47	40.	0.	0.	40.	31	92	23.	0.	3.	26.
20	55	10.	0.	0.	10.	25	51	10.	0.	0.	10.	32	15	7.	0.	0.	2.
20	57	44.	0.	0.	44.	25	52	46.	29.	0.	74.	32	22	14.	0.	0.	14.
20	58	2.	0.	0.	2.	25	53	14.	0.	0.	14.	32	23	35.	0.	0.	35.
20	76	1.	1.	0.	2.	25	54	28.	0.	0.	28.	32	27	0.	0.	15.	15.
20	78	10.	0.	0.	10.	25	57	38.	0.	0.	38.	32	30	1.	0.	0.	1.
20	81	7.	0.	0.	7.	25	62	17.	0.	0.	17.	32	31	1.	28.	0.	29.
20	82	9.	0.	0.	9.	25	64	8.	0.	0.	8.	32	32	0.	34.	0.	34.
21	22	0.	0.	13.	13.	25	65	63.	0.	0.	63.	32	39	0.	20.	0.	20.
21	23	0.	0.	11.	11.	25	75	3.	0.	0.	3.	32	40	1.	53.	7.	61.
21	24	0.	15.	36.	51.	25	78	2.	0.	0.	2.	32	41	0.	33.	0.	33.
21	25	0.	9.	5.	14.	25	81	10.	0.	0.	10.	32	49	12.	0.	0.	12.
21	26	0.	4.	2.	6.	25	82	2.	0.	0.	2.	32	51	0.	0.	17.	27.
21	27	0.	0.	10.	10.	26	17	0.	0.	20.	20.	32	53	0.	0.	25.	43.
21	28	2.	10.	37.	49.	26	18	5.	0.	32.	37.	32	54	0.	43.	0.	43.
21	34	0.	0.	11.	11.	26	25	11.	0.	1.	12.	32	55	0.	10.	0.	63.
21	38	0.	0.	4.	4.	26	36	17.	0.	40.	57.	32	59	4.	0.	0.	4.
21	39	0.	0.	10.	10.	26	37	4.	0.	0.	4.	32	62	7.	2.	0.	9.
21	50	6.	0.	0.	6.	26	38	4.	0.	0.	4.	32	63	9.	7.	0.	16.
21	51	38.	0.	0.	38.	26	40	10.	0.	0.	10.	32	65	7.	0.	0.	7.
21	52	56.	0.	0.	56.	26	41	5.	0.	0.	5.	32	66	62.	0.	3.	65.
21	53	13.	0.	0.	13.	26	44	8.	0.	0.	8.	32	77	25.	7.	0.	28.
21	54	40.	0.	0.	40.	26	51	6.	0.	0.	6.	32	78	15.	32.	24.	71.
21	57	26.	0.	0.	26.	26	52	60.	13.	0.	73.	32	79	48.	2.	0.	50.
21	58	71.	0.	0.	71.	26	53	16.	0.	0.	16.	32	80	47.	0.	0.	47.
21	70	22.	0.	0.	22.	26	55	2.	0.	0.	2.	32	81	26.	0.	0.	27.
22	24	4.	4.	12.	20.	26	62	30.	0.	0.	30.	32	82	10.	0.	0.	10.
22	25	0.	0.	11.	11.	26	65	16.	0.	0.	16.	32	83	15.	0.	0.	15.
22	26	0.	1.	33.	34.	27	25	1.	0.	0.	1.	32	84	6.	0.	0.	6.
22	27	0.	0.	42.	42.	27	36	10.	0.	10.	40.	32	85	18.	5.	28.	51.
22	28	0.	0.	55.	55.	27	37	0.	0.	20.	20.	32	86	0.	0.	11.	11.
22	29	0.	0.	40.	40.	27	42	4.	0.	0.	4.	32	87	3.	0.	0.	3.
22	30	2.	0.	37.	39.	27	43	4.	0.	0.	4.	33	23	6.	0.	0.	6.
22	31	0.	0.	24.	24.	27	50	0.	0.	2.	2.	33	26	17.	0.	0.	17.
22	32	0.	0.	20.	20.	27	51	16.	0.	2.	18.	33	27	14.	0.	0.	14.
22	33	0.	0.	21.	21.	27	52	30.	0.	0.	30.	33	31	19.	0.	0.	19.
22	38	0.	0.	14.	14.	27	53	12.	0.	0.	12.	33	39	0.	0.	0.	0.
22	39	0.	0.	50.	50.	27	55	4.	0.	0.	4.	33	40	2.	11.	0.	13.
22	49	0.	0.	2.	2.	27	56	40.	0.	0.	40.	33	41	6.	51.	5.	60.
22	51	3.	0.	0.	3.	27	57	4.	0.	0.	4.	33	43	0.	0.	11.	11.
22	53	10.	0.	0.	10.	27	60	4.	0.	0.	4.	33	44	0.	0.	22.	22.
22	54	7.	0.	0.	7.	27	61	27.	0.	0.	27.	33	45	9.	0.	0.	9.
22	57	22.	0.	0.	22.	27	62	4.	0.	0.	4.	33	46	3.	0.	0.	3.
22	58	31.	0.	0.	31.	27	80	20.	0.	0.	20.	33	47	5.	0.	0.	5.
22	59	9.	0.	0.	9.	27	86	1.	0.	0.	1.	33	48	5.	0.	0.	5.
22	62	12.	0.	0.	12.	28	23	10.	0.	5.	15.	33	50	3.	0.	7.	10.
22	70	6.	0.	0.	6.	28	24	1.	0.	0.	1.	33	51	6.	0.	45.	51.
22	82	2.	0.	0.	2.	28	27	0.	0.	4.	4.	33	52	2.	0.	0.	2.
22	85	20.	0.	0.	20.	28	28	0.	0.	13.	13.	33	53	0.	0.	53.	53.
22	92	10.	0.	0.	10.	28	36	0.	0.	3.	3.	33	54	0.	13.	0.	13.
23	23	1.	0.	0.	1.	28	37	0.	0.	94.	94.	33	55	28.	14.	3.	45.
23	24	4.	0.	4.	8.	28	44	2.	0.	0.	2.	33	56	31.	0.	0.	31.
23	25	10.	20.	4.	34.	28	49	10.	0.	4.	14.	33	57	3.	0.	0.	3.
23	26	7.	1.	26.	34.	28	50	6.	0.	2.	8.	33	59	12.	0.	0.	12.
23	27	0.	0.	1.	1.	28	51	1.	0.	0.	1.	33	62	0.	4.	0.	4.
23	30	4.	0.	5.	9.	28	53	25.	0.	0.	25.	33	63	0.	14.	0.	14.
23	31	0.	0.	01.	01.	28	55	7.	0.	0.	7.	33	65	5.	0.	0.	5.
23	32	0.	0.	84.	84.	28	58	0.	75.	0.	75.	33	66	9.	0.	0.	9.
23	33	0.	0.	27.	27.	28	59	25.	36.	0.	61.	33	67	2.	0.	0.	2.
23	34	0.	0.	19.	19.	28	60	29.	0.	0.	29.	33	78	17.	8.	4.	24.
23	35	5.	0.	24.	29.	28	61	12.	0.	0.	12.	33	79	25.	25.	0.	50.
23	36	40.	0.	3.	43.	28	63	6.	0.	0.	6.	33	80	72.	10.	0.	82.
23	37	8.	0.	0.	8.	28	75	10.	4.	0.	14.	33	81	6.	2.	10.	18.
23	39	0.	0.	37.	37.	28	76	0.	5.	0.	5.	33	82	5.	10.	0.	15.
23	40	1.	0.	0.	1.	28	79	7.	0.	0.	7.	33	83	0.	41.	0.	41.
23	44	6.	0.	0.	6.	29	23	1.	0.	0.	1.	33	84	2.	1.	0.	3.
23	46	6.	0.	0.	6.	29	30	2.	0.</								

TABLE A.7 (Contd.)

X	Y	M1	M2	M3	TOTAL	X	Y	M1	M2	M3	TOTAL	X	Y	M1	M2	M3	TOTAL
34	61	6.	0.	0.	6.	38	42	3.	0.	70.	73.	42	61	6.	0.	0.	6.
34	62	1.	0.	0.	1.	38	43	4.	0.	0.	4.	43	19	6.	0.	0.	6.
34	63	29.	0.	0.	29.	38	44	3.	6.	53.	62.	43	20	1.	0.	0.	1.
34	64	3.	0.	0.	3.	38	45	8.	36.	45.	89.	43	22	0.	0.	5.	5.
34	68	3.	0.	0.	3.	38	47	6.	32.	0.	38.	43	27	2.	0.	0.	2.
34	77	19.	0.	0.	19.	38	49	0.	8.	0.	8.	43	28	22.	7.	0.	29.
34	78	14.	2.	0.	16.	38	52	26.	0.	0.	26.	43	29	5.	22.	0.	27.
34	79	0.	7.	0.	7.	38	56	5.	0.	0.	5.	43	31	0.	9.	0.	9.
34	87	0.	0.	30.	30.	38	57	2.	0.	0.	2.	43	32	20.	2.	0.	22.
34	90	0.	44.	0.	44.	38	58	5.	0.	0.	5.	43	33	0.	27.	42.	69.
34	91	0.	7.	0.	7.	38	59	44.	2.	0.	47.	43	34	12.	0.	0.	12.
35	11	6.	0.	0.	6.	38	60	21.	1.	0.	22.	43	35	15.	0.	10.	35.
35	23	1.	0.	0.	1.	38	64	5.	0.	0.	5.	43	36	15.	0.	0.	15.
35	25	3.	0.	0.	3.	38	65	3.	0.	0.	3.	43	40	6.	0.	0.	6.
35	27	33.	0.	0.	33.	39	19	3.	0.	0.	3.	43	41	15.	10.	0.	25.
35	36	5.	0.	0.	5.	39	22	8.	0.	0.	8.	43	42	10.	0.	0.	10.
35	38	0.	0.	5.	5.	39	23	24.	0.	0.	24.	43	43	8.	26.	0.	34.
35	41	0.	5.	0.	5.	39	33	22.	0.	18.	40.	43	44	1.	18.	0.	19.
35	42	2.	5.	50.	57.	39	34	15.	0.	7.	17.	43	45	0.	43.	10.	73.
35	43	19.	34.	33.	86.	39	35	17.	0.	0.	17.	43	46	6.	2.	4.	12.
35	44	6.	2.	79.	87.	39	36	5.	0.	0.	5.	43	47	0.	4.	60.	64.
35	45	14.	0.	11.	25.	39	37	1.	0.	0.	1.	43	48	7.	24.	0.	32.
35	48	12.	0.	0.	12.	39	39	8.	0.	0.	8.	43	50	17.	24.	0.	41.
35	49	61.	0.	0.	61.	39	41	0.	0.	55.	55.	43	52	15.	0.	15.	30.
35	53	1.	0.	0.	1.	39	42	0.	0.	70.	70.	43	53	19.	19.	15.	53.
35	54	2.	0.	0.	2.	39	44	4.	9.	0.	13.	43	54	5.	0.	0.	5.
35	60	2.	0.	0.	2.	39	45	0.	24.	52.	76.	43	55	9.	0.	0.	9.
35	64	28.	0.	0.	28.	39	46	0.	4.	37.	41.	43	56	8.	5.	0.	13.
35	65	5.	0.	0.	5.	39	47	11.	48.	2.	61.	43	57	2.	5.	0.	7.
35	68	8.	0.	0.	8.	39	48	14.	43.	0.	57.	43	59	4.	0.	0.	4.
35	69	20.	8.	0.	28.	39	49	18.	26.	0.	44.	43	60	2.	0.	0.	2.
35	70	8.	0.	0.	8.	39	50	0.	0.	0.	0.	43	61	5.	0.	0.	5.
35	73	7.	0.	0.	7.	39	51	5.	0.	0.	5.	44	16	1.	0.	0.	1.
35	81	0.	0.	25.	25.	39	52	17.	1.	0.	18.	44	21	3.	16.	0.	19.
35	82	10.	0.	6.	16.	39	55	6.	0.	0.	6.	44	22	2.	10.	31.	43.
35	83	2.	0.	0.	2.	39	56	10.	0.	0.	10.	44	23	6.	0.	8.	14.
35	84	1.	0.	0.	1.	39	57	6.	0.	0.	6.	44	24	0.	0.	5.	5.
35	85	2.	0.	0.	2.	39	60	10.	0.	0.	10.	44	25	3.	0.	0.	3.
35	90	0.	4.	0.	4.	39	61	10.	0.	0.	10.	44	26	5.	0.	0.	5.
35	91	14.	0.	0.	14.	39	62	1.	6.	0.	9.	44	27	10.	29.	0.	39.
35	92	6.	0.	0.	6.	39	63	3.	0.	0.	3.	44	28	1.	48.	0.	49.
36	10	0.	0.	0.	0.	39	64	10.	0.	0.	10.	44	29	10.	15.	0.	25.
36	11	5.	0.	6.	11.	40	21	2.	0.	0.	2.	44	30	0.	22.	0.	22.
36	12	4.	3.	0.	7.	40	22	24.	0.	0.	24.	44	31	0.	27.	0.	27.
36	22	0.	29.	0.	29.	40	23	12.	0.	0.	12.	44	32	28.	14.	0.	42.
36	23	0.	17.	0.	17.	40	29	13.	0.	0.	13.	44	33	33.	33.	0.	66.
36	26	4.	0.	0.	4.	40	31	15.	0.	5.	20.	44	34	5.	4.	0.	9.
36	27	51.	0.	0.	51.	40	34	15.	4.	44.	63.	44	35	13.	20.	0.	33.
36	35	8.	0.	3.	11.	40	35	1.	0.	3.	4.	44	36	10.	5.	0.	15.
36	36	5.	12.	2.	19.	40	41	7.	43.	0.	50.	44	37	7.	6.	0.	13.
36	37	15.	8.	0.	23.	40	42	18.	10.	0.	28.	44	38	1.	0.	0.	1.
36	38	7.	46.	3.	56.	40	43	21.	0.	0.	21.	44	39	13.	0.	0.	13.
36	39	26.	14.	0.	40.	40	44	27.	0.	27.	40.	44	40	1.	0.	0.	14.
36	40	0.	18.	0.	18.	40	45	10.	60.	5.	75.	44	41	8.	5.	0.	13.
36	41	0.	24.	0.	24.	40	46	2.	14.	22.	38.	44	43	6.	0.	0.	6.
36	42	0.	59.	25.	64.	40	47	12.	17.	0.	29.	44	44	5.	10.	0.	15.
36	43	18.	2.	0.	20.	40	48	3.	16.	3.	22.	44	45	4.	4.	84.	92.
36	44	11.	0.	17.	28.	40	49	23.	14.	0.	37.	44	46	6.	11.	25.	42.
36	45	10.	0.	0.	10.	40	50	21.	37.	0.	58.	44	47	9.	18.	36.	63.
36	48	5.	17.	0.	22.	40	51	16.	23.	0.	39.	44	48	7.	23.	0.	30.
36	49	3.	3.	0.	6.	40	52	18.	15.	0.	33.	44	49	36.	0.	0.	36.
36	53	2.	0.	0.	2.	40	53	21.	8.	0.	29.	44	50	15.	35.	0.	50.
36	54	3.	0.	0.	3.	40	54	17.	1.	0.	18.	44	51	0.	10.	46.	56.
36	57	1.	0.	0.	1.	40	55	8.	0.	0.	8.	44	52	18.	7.	30.	55.
36	58	2.	0.	0.	2.	40	56	4.	0.	0.	4.	44	53	13.	3.	0.	16.
36	64	71.	0.	0.	71.	40	57	2.	17.	0.	19.	44	54	4.	0.	0.	4.
36	65	25.	0.	0.	25.	40	60	4.	0.	0.	4.	45	12	2.	0.	0.	2.
36	66	12.	0.	0.	12.	41	20	7.	0.	0.	7.	45	17	5.	0.	0.	5.
36	70	5.	0.	0.	5.	41	23	17.	0.	0.	17.	45	19	13.	0.	0.	13.
36	71	18.	0.	0.	18.	41	29	16.	0.	0.	16.	45	22	21.	16.	47.	84.
36	72	25.	0.	0.	25.	41	30	21.	0.	0.	21.	45	23	0.	0.	73.	73.
36	81	0.	0.	12.	12.	41	32	4.	0.	0.	4.	45	24	6.	16.	77.	99.
36	82	0.	0.	27.	27.	41	33	7.	0.	18.	25.	45	25	17.	0.	11.	28.
36	83	0.	0.	20.	20.	41	34	39.	0.	30.	69.	45	26	9.	5.	15.	5.
36	84	2.	0.	87.	89.	41	38	4.	0.	12.	16.	45	27	0.	42.	0.	62.
36	85	6.	0.	45.	51.	41	40	7.	0.	0.	7.	45	28	0.	73.	0.	73.
36	86	0.	0.	7.	7.	41	41	5.	25.	0.	30.	45	29	69.	0.	0.	69.
36	88	0.	11.	0.	11.	41	42	1.	0.	0.	1.	45	30	46.	0.	0.	46.
36	89	0.	15.	0.	15.	41	43	3.	0.	0.	3.	45	31	16.	0.	0.	16.
36	90	0.	2.	0.	2.	41	44	24.	23.	0.	47.	45	32	8.	0.	0.	8.
37	20	0.	2.	0.	2.	41	45	10.	0.	60.	70.	45	33	5.	0.	0.	5.
37	26	7.	0.	0.	7.	41	46	6.	0.	61.	67.	45	34	0.	1.	36.	37.
37	27	11.	0.	0.	11.	41	47	4.	2.	0.	6.	45	35	4.	0.	0.	4.
37	35	19.	0.	11.	30.	41	48	7.	0.	0.	7.	45	36	2.	0.	0.	2.
37	36	0.	2.	6.	6.	41	49	15.	0.	15.	0.	45	37	6.	0.	0.	6.
37	37	12.	0.	0.	12.	41	50	6.	0.	0.	6.	45	39	18.	11.	0.	29.
37	38	30.	0.	0.	30.	41	51	10.	1.	0.	11.	45	40	37.	16.	0.	53.
37	41	0.	0.	48.	48.	41	52	16.	0.	0.	16.	45	41	13.	0.	0.	13.
37	42	5.	0.	70.	75.	41	53	3.	0.	0.	3.	45	42	9.	4.	0.	13.
37	43	25.	0.	0.	25.	41	54	23.	0.	0.	23.	45	43	19.	0.	0.	19.
37	44	0.	37.	22.	59.	41	59	0.	70.	0.	70.	45	44	46.	0.	0.	46.
37	45	9.	15.	0.	24.	42	20	15.	0.	0.	15.	45	45	15.	25.	0.	40.
37	52	13.	5.	0.	18.	42	21	6.	0.	0.	6.	45	46	26.	0.	0.	26.
37	53	9.	9.	0.	18.	42	23	9.	0.	45.	57.	45	47	19.	10.	6.	35.
37	54	1.	0.	0.	1.	42	29	4.	51.	0.	56.	45	48	3.	67.	9.	74.
37	57	2.	0.	0.	2.	42	30	9.	0.	0.	9.	45	49	0.	32.	0.	32.
37	58	2.	0.	0.	2.	42	32	21.	0.	0.	21.	45	50	28.	17.	0.	45.
37	59	24.	0.	0.	24.	42	33	26.	14.	51.	91.	45	51	5.	4.	5.	14.
37	60	3.	0.	0.	3.	42	34	2.	0.	15.	17.	46</					

TABLE A.7 (Contd.)

X	Y	M1	M2	M3	TOTAL
46	42	18.	6.	0.	24.
46	43	3.	0.	0.	3.
46	44	2.	0.	0.	2.
46	45	5.	0.	0.	5.
46	47	17.	15.	0.	32.
46	48	2.	2.	0.	4.
47	22	38.	0.	0.	38.
47	23	13.	0.	0.	13.
47	24	10.	0.	0.	10.
47	25	5.	0.	0.	5.
47	27	0.	1.	0.	1.
47	28	10.	0.	0.	10.
47	29	18.	4.	0.	22.
47	30	3.	8.	0.	11.
47	32	7.	0.	21.	28.
47	33	0.	0.	22.	22.
47	34	5.	0.	30.	35.
47	35	0.	0.	30.	30.
47	36	0.	0.	14.	14.
47	37	1.	6.	72.	80.
47	38	18.	0.	52.	70.
47	39	30.	0.	0.	30.
47	40	11.	0.	0.	11.
47	41	24.	0.	0.	24.
47	42	3.	0.	0.	3.
48	23	4.	0.	0.	4.
48	28	15.	0.	0.	15.
48	29	17.	32.	0.	49.
48	30	0.	7.	0.	7.
48	31	0.	0.	3.	3.
48	32	0.	3.	92.	95.
48	33	0.	2.	32.	34.
48	34	0.	0.	84.	84.
48	35	0.	0.	58.	58.
48	36	0.	0.	57.	57.
48	37	3.	8.	83.	94.
48	38	6.	13.	24.	43.
48	39	18.	0.	0.	18.
48	40	18.	0.	0.	18.
48	41	1.	0.	0.	1.
49	13	1.	0.	0.	1.
49	22	5.	0.	0.	5.
49	23	30.	5.	0.	35.
49	28	8.	0.	0.	8.
49	29	41.	0.	0.	41.
49	31	0.	20.	16.	36.
49	32	0.	70.	8.	78.
49	33	0.	12.	30.	42.
49	34	0.	14.	28.	42.
49	35	0.	8.	73.	81.
49	36	0.	1.	98.	100.
49	37	3.	4.	65.	72.
49	38	17.	1.	27.	45.
49	39	33.	0.	1.	34.
49	40	8.	0.	0.	8.
50	23	10.	0.	0.	10.
50	31	0.	4.	10.	14.
50	32	0.	52.	2.	54.
50	33	14.	1.	5.	20.
50	34	18.	0.	8.	26.
50	35	0.	27.	28.	55.
50	36	14.	4.	17.	35.
50	37	10.	0.	4.	16.
50	38	11.	0.	71.	82.
50	39	4.	0.	68.	72.
50	40	5.	0.	84.	89.
61	58	28.	0.	0.	28.

TABLE A.8. X,Y Listing of 1970 Data for
Light and Heavy Manufacturing

X	Y	M1+M2	M3	TOTAL	X	Y	M1+M2	M3	TOTAL	X	Y	M1+M2	M3	TOTAL	X	Y	M1+M2	M3	TOTAL
C 40.	1.	0.	1.	11 43	4.	2.	6.	14 49	16.	0.	16.	18 31	0.	7.	7.				
0 42.	2.	0.	2.	11 45	39.	0.	39.	14 50	92.	0.	92.	18 33	0.	54.	54.				
0 69.	1.	0.	1.	11 47	2.	6.	8.	14 51	37.	0.	37.	18 34	0.	51.	51.				
0 90.	1.	0.	1.	11 48	13.	1.	14.	14 52	80.	0.	80.	18 37	27.	0.	27.				
1 42.	0.	4.	4.	11 49	27.	0.	27.	14 53	48.	0.	48.	18 58	6.	0.	6.				
1 46.	3.	0.	3.	11 52	30.	0.	30.	14 54	18.	0.	18.	19 7	1.	4.	5.				
1 63.	0.	1.	1.	11 53	12.	0.	12.	14 57	36.	0.	36.	19 8	0.	8.	8.				
1 91.	1.	0.	1.	11 57	1.	6.	7.	14 58	11.	30.	41.	19 22	0.	5.	5.				
2 44.	3.	0.	3.	11 58	0.	6.	6.	14 59	23.	67.	90.	19 23	0.	68.	68.				
2 46.	1.	0.	1.	11 59	9.	21.	30.	14 60	12.	4.	16.	19 24	0.	68.	68.				
2 50.	1.	0.	1.	11 60	3.	0.	3.	14 61	1.	0.	1.	19 25	0.	6.	6.				
2 51.	0.	5.	5.	11 61	3.	0.	3.	14 63	1.	0.	1.	19 27	1.	0.	1.				
2 54.	1.	0.	1.	11 62	21.	17.	38.	14 73	4.	0.	4.	19 28	5.	0.	5.				
2 58.	2.	0.	2.	11 63	19.	0.	19.	14 74	10.	0.	10.	19 32	0.	3.	3.				
2 64.	2.	0.	2.	11 64	1.	0.	1.	14 76	16.	0.	16.	19 33	0.	44.	44.				
2 65.	4.	0.	4.	11 65	0.	2.	2.	14 82	1.	0.	1.	19 43	7.	0.	7.				
3 51.	0.	8.	8.	11 66	0.	13.	13.	15 6	0.	2.	2.	19 51	19.	0.	19.				
3 61.	3.	0.	3.	11 67	3.	15.	18.	15 16	0.	40.	40.	19 52	1.	0.	1.				
3 65.	3.	0.	3.	11 70	16.	0.	16.	15 17	0.	100.	100.	19 54	32.	0.	32.				
3 81.	10.	6.	16.	11 71	28.	18.	46.	15 18	0.	61.	61.	19 55	10.	0.	10.				
3 82.	18.	6.	24.	11 72	28.	0.	28.	15 19	4.	36.	40.	19 57	25.	0.	25.				
3 83.	16.	0.	16.	11 73	36.	0.	36.	15 20	0.	2.	2.	19 58	4.	0.	4.				
4 61.	1.	0.	1.	11 74	44.	0.	44.	15 21	0.	4.	4.	19 63	27.	0.	27.				
4 69.	2.	0.	2.	11 75	42.	0.	42.	15 22	2.	5.	7.	19 77	7.	0.	7.				
4 70.	1.	0.	1.	11 76	9.	0.	9.	15 24	1.	0.	1.	19 78	10.	0.	10.				
4 71.	1.	6.	7.	11 83	8.	0.	8.	15 25	7.	0.	7.	20 23	0.	34.	34.				
4 79.	9.	0.	9.	11 91	0.	6.	6.	15 30	2.	0.	2.	20 24	3.	16.	19.				
4 80.	2.	0.	2.	11 92	8.	10.	18.	15 31	23.	0.	23.	20 28	30.	0.	30.				
4 81.	6.	0.	6.	11 93	0.	4.	4.	15 32	26.	0.	26.	20 38	0.	4.	4.				
4 91.	0.	2.	2.	12 41	0.	1.	1.	15 33	33.	0.	33.	20 43	18.	0.	18.				
4 92.	4.	0.	4.	12 42	8.	29.	37.	15 36	14.	0.	14.	20 44	0.	1.	1.				
4 93.	4.	0.	4.	12 43	13.	4.	17.	15 37	2.	0.	2.	20 48	0.	8.	8.				
5 50.	3.	0.	3.	12 44	10.	8.	18.	15 38	3.	0.	3.	20 49	0.	20.	20.				
5 56.	2.	0.	2.	12 45	26.	17.	43.	15 42	0.	62.	62.	20 50	3.	0.	3.				
5 69.	19.	0.	19.	12 48	15.	8.	23.	15 43	12.	24.	36.	20 51	53.	0.	53.				
5 70.	8.	8.	16.	12 49	8.	31.	39.	15 44	9.	0.	9.	20 52	58.	0.	58.				
5 71.	1.	0.	1.	12 50	2.	0.	2.	15 45	23.	0.	23.	20 53	26.	0.	26.				
5 78.	2.	0.	2.	12 52	44.	0.	44.	15 49	22.	0.	22.	20 54	46.	0.	46.				
5 79.	32.	0.	32.	12 53	12.	0.	12.	15 50	68.	0.	68.	20 55	10.	0.	10.				
5 80.	32.	0.	32.	12 57	8.	40.	48.	15 51	24.	0.	24.	20 57	44.	0.	44.				
5 81.	6.	0.	6.	12 58	1.	9.	10.	15 52	32.	0.	32.	20 58	2.	0.	2.				
5 84.	4.	0.	4.	12 59	0.	32.	32.	15 56	4.	0.	4.	20 76	2.	0.	2.				
5 91.	6.	3.	9.	12 60	13.	8.	21.	15 57	68.	0.	68.	20 78	10.	0.	10.				
5 92.	1.	1.	2.	12 61	8.	0.	8.	15 58	14.	0.	14.	20 81	7.	0.	7.				
5 93.	4.	0.	4.	12 62	6.	0.	6.	15 59	11.	0.	11.	20 82	9.	0.	9.				
6 40.	0.	12.	12.	12 63	4.	0.	4.	15 60	3.	0.	3.	21 22	0.	13.	13.				
6 42.	2.	0.	2.	12 66	20.	5.	25.	15 72	8.	0.	8.	21 23	0.	11.	11.				
6 48.	1.	0.	1.	12 67	29.	16.	45.	15 73	10.	0.	10.	21 24	15.	36.	51.				
6 50.	4.	0.	4.	12 68	1.	19.	20.	15 88	8.	0.	8.	21 25	9.	5.	14.				
6 59.	1.	0.	1.	12 71	0.	14.	14.	15 89	6.	1.	7.	21 26	4.	2.	6.				
6 69.	3.	0.	3.	12 73	1.	0.	1.	16 10	0.	23.	23.	21 27	0.	10.	10.				
6 78.	8.	0.	8.	12 74	22.	0.	22.	16 11	1.	10.	11.	21 28	12.	37.	49.				
6 79.	20.	0.	20.	12 75	4.	0.	4.	16 16	0.	20.	20.	21 34	0.	11.	11.				
6 91.	6.	0.	6.	12 77	14.	0.	14.	16 17	0.	84.	84.	21 38	0.	4.	4.				
6 92.	1.	0.	1.	12 78	2.	0.	2.	16 18	0.	82.	82.	21 39	0.	10.	10.				
7 40.	0.	54.	54.	12 79	1.	0.	1.	16 19	5.	23.	28.	21 50	4.	0.	4.				
7 62.	8.	0.	8.	12 80	6.	0.	6.	16 20	0.	65.	65.	21 51	38.	0.	38.				
7 63.	3.	2.	5.	12 81	8.	2.	10.	16 21	2.	24.	26.	21 52	56.	0.	56.				
7 65.	0.	2.	2.	12 83	5.	0.	5.	16 22	7.	3.	10.	21 53	13.	0.	13.				
7 66.	2.	4.	6.	12 85	8.	0.	8.	16 24	5.	0.	5.	21 54	40.	0.	40.				
7 68.	1.	0.	1.	12 86	1.	0.	1.	16 25	16.	0.	16.	21 57	26.	0.	26.				
7 75.	4.	0.	4.	12 92	2.	0.	2.	16 27	7.	0.	7.	21 58	71.	0.	71.				
7 92.	3.	0.	3.	13 3	0.	9.	9.	16 30	1.	4.	5.	21 70	22.	0.	22.				
8 40.	8.	61.	71.	13 4	0.	47.	47.	16 31	5.	56.	61.	22 24	8.	12.	20.				
8 41.	1.	5.	6.	13 5	0.	30.	30.	16 32	20.	40.	60.	22 25	9.	2.	11.				
8 44.	1.	1.	2.	13 6	0.	37.	37.	16 33	23.	17.	33.	22 26	37.	34.	71.				
8 45.	0.	19.	19.	13 16	0.	2.	2.	16 34	0.	6.	6.	22 27	0.	82.	82.				
8 48.	1.	0.	1.	13 22	0.	9.	9.	16 35	0.	2.	2.	22 28	0.	55.	55.				
8 50.	6.	0.	6.	13 42	4.	72.	76.	16 36	3.	4.	7.	22 29	0.	40.	40.				
8 52.	6.	0.	6.	13 44	0.	42.	42.	16 42	6.	40.	46.	22 30	2.	37.	39.				
8 62.	2.	0.	2.	13 49	1.	0.	1.	16 43	16.	10.	26.	22 31	0.	29.	29.				
8 66.	2.	0.	2.	13 57	0.	7.	7.	16 46	10.	0.	10.	22 37	0.	70.	70.				
8 77.	4.	0.	4.	13 58	55.	1.	56.	16 52	23.	0.	23.	22 33	0.	21.	21.				
9 40.	5.	2.	7.	13 59	82.	8.	90.	16 72	8.	0.	8.	22 38	0.	14.	14.				
9 41.	16.	23.	39.	13 60	8.	0.	8.	16 79	1.	0.	1.	22 39	0.	50.	50.				
9 42.	6.	15.	21.	13 61	6.	0.	6.	16 81	12.	0.	12.	22 49	0.	2.	2.				
9 43.	0.	22.	22.	13 62	3.	0.	3.	16 88	9.	0.	9.	22 51	3.	0.	3.				
9 44.	14.	14.	28.	13 63	5.	0.	5.	17 10	0.	15.	15.	22 53	10.	0.	10.				
9 45.	13.	5.	18.	13 66	5.	0.	5.	17 11	4.	1.	5.	22 54	7.	0.	7.				
9 48.	0.	3.	3.	13 67	2.	0.	2.	17 18	0.	9.	9.	22 57	22.	0.	22.				
9 49.	0.	11.	11.	13 69	1.	4.	5.	17 19	0.	18.	18.	22 58	31.	0.	31.				
9 50.	0.	28.	28.	13 72	6.	0.	6.	17 20	0.	100.	100.	22 59	9.	0.	9.				
9 52.	18.	10.	28.	13 73	3.	0.	3.	17 21	0.	97.	97.	22 62	12.	0.	12.				
9 53.	5.	0.	5.	13 74	1.	47.	48.	17 22	0.	72.	72.	22 70	6.	0.	6.				
9 60.	24.	0.	24.	13 75	0.	14.	14.	17 23	0.	36.	36.	22 82	2.	0.	2.				
9 61.	1.	0.	1.	13 81	18.	3.	21.	17 25	1.	1.	2.	22 85	20.	0.	20.				
9 63.	2.	0.	2.	13 82	2.	0.	2.	17 30	1.	18.	19.	22 92	10.	0.	10.				
9 91.	0.	2.	2.	13 83	14.	0.	14.	17 31	0.	70.	70.	23 23	1.	0.	1.				
10 39.	0.	8.	8.	13 89	3.	0.	3.	17 32	0.	59.	59.	23 24	4.	4.	8.				
10 4																			

TABLE A.8 (Contd.)

X	Y	M1+M2	M3	TOTAL	X	Y	M1+M2	M3	TOTAL	X	Y	M1+M2	M3	TOTAL	X	Y	M1+M2	M3	TOTAL
23	87	13.	0.	13.	29	57	58.	0.	58.	34	43	34.	44.	78.	37	69	7.	0.	7.
23	88	11.	0.	11.	29	58	91.	0.	91.	34	44	0.	95.	95.	37	70	8.	0.	8.
23	89	5.	7.	12.	29	59	79.	0.	79.	34	45	2.	0.	2.	37	85	0.	43.	43.
23	91	2.	0.	2.	29	60	15.	40.	55.	34	49	7.	0.	7.	37	89	61.	0.	61.
23	92	4.	0.	4.	29	63	14.	0.	14.	34	50	22.	0.	22.	37	90	15.	0.	15.
24	23	3.	0.	3.	29	70	45.	0.	45.	34	52	4.	0.	4.	37	91	57.	0.	57.
24	25	6.	0.	6.	30	27	2.	0.	2.	34	53	0.	52.	52.	38	17	2.	0.	2.
24	26	9.	0.	9.	30	33	2.	0.	2.	34	54	25.	0.	25.	38	34	0.	7.	7.
24	34	0.	53.	53.	30	38	23.	28.	51.	34	55	38.	1.	39.	38	35	9.	95.	94.
24	35	6.	59.	65.	30	39	16.	0.	16.	34	56	7.	0.	7.	38	36	10.	17.	27.
24	36	17.	27.	44.	30	52	12.	0.	12.	34	60	3.	0.	3.	38	37	18.	0.	18.
24	37	41.	0.	41.	30	53	15.	0.	15.	34	61	6.	0.	6.	38	38	5.	0.	5.
24	43	5.	0.	5.	30	54	20.	0.	20.	34	62	1.	0.	1.	38	41	0.	55.	55.
24	44	38.	0.	38.	30	55	70.	3.	73.	34	63	29.	0.	29.	38	42	3.	70.	73.
24	46	16.	0.	16.	30	56	21.	0.	21.	34	64	3.	0.	3.	38	43	4.	0.	4.
24	50	10.	0.	10.	30	58	32.	0.	32.	34	68	3.	0.	3.	38	44	9.	51.	62.
24	51	6.	0.	6.	30	59	71.	0.	80.	34	77	19.	0.	19.	38	45	44.	45.	95.
24	52	6.	0.	6.	30	67	7.	0.	7.	34	78	16.	0.	16.	38	47	38.	0.	38.
24	53	20.	0.	20.	30	68	12.	0.	12.	34	79	7.	0.	7.	38	49	8.	0.	8.
24	55	6.	0.	6.	30	69	7.	0.	7.	34	87	0.	30.	30.	38	52	26.	0.	26.
24	56	5.	0.	5.	30	70	18.	0.	18.	34	90	44.	0.	44.	38	56	5.	0.	5.
24	57	12.	0.	12.	30	71	6.	0.	6.	34	91	7.	0.	7.	38	57	2.	0.	2.
24	61	17.	0.	17.	30	72	22.	0.	22.	35	11	6.	0.	6.	38	58	5.	0.	5.
24	62	60.	0.	60.	30	78	15.	0.	15.	35	23	1.	0.	1.	38	59	47.	0.	47.
24	63	4.	0.	4.	31	15	1.	0.	1.	35	25	3.	0.	3.	38	60	22.	0.	22.
24	64	25.	0.	25.	31	39	42.	0.	42.	35	27	33.	0.	33.	38	64	5.	0.	5.
24	65	5.	0.	5.	31	49	5.	0.	5.	35	36	5.	0.	5.	38	65	1.	0.	1.
24	66	5.	0.	5.	31	51	48.	16.	64.	35	38	0.	5.	5.	38	66	3.	0.	3.
24	73	20.	0.	20.	31	53	40.	0.	40.	35	41	5.	0.	5.	39	22	8.	0.	8.
24	85	12.	0.	12.	31	54	50.	0.	50.	35	42	7.	40.	47.	39	23	24.	0.	24.
25	12	4.	0.	4.	31	55	72.	11.	83.	35	43	53.	33.	86.	39	33	22.	13.	40.
25	34	0.	4.	4.	31	58	19.	0.	19.	35	44	8.	79.	87.	39	34	15.	2.	17.
25	35	0.	11.	11.	31	59	18.	0.	18.	35	45	14.	11.	25.	39	35	17.	0.	17.
25	36	12.	71.	83.	31	65	58.	0.	58.	35	48	12.	0.	12.	39	36	5.	0.	5.
25	37	100.	0.	100.	31	66	45.	0.	45.	35	49	61.	0.	61.	39	37	1.	0.	1.
25	38	16.	0.	16.	31	67	49.	0.	49.	35	53	1.	0.	1.	39	39	8.	0.	8.
25	45	5.	0.	5.	31	68	13.	0.	13.	35	54	2.	0.	2.	39	41	0.	55.	55.
25	46	27.	0.	27.	31	69	4.	0.	4.	35	60	2.	0.	2.	39	42	0.	70.	70.
25	47	40.	0.	40.	31	82	21.	0.	21.	35	64	28.	0.	28.	39	44	13.	0.	13.
25	51	10.	0.	10.	31	87	14.	0.	14.	35	65	5.	0.	5.	39	45	25.	52.	74.
25	52	74.	0.	74.	31	88	10.	0.	10.	35	68	8.	0.	8.	39	46	4.	17.	41.
25	53	14.	0.	14.	31	92	23.	1.	24.	35	69	28.	0.	28.	39	47	50.	2.	51.
25	56	28.	0.	28.	32	15	2.	0.	2.	35	70	8.	0.	8.	39	48	57.	0.	57.
25	57	38.	0.	38.	32	22	14.	0.	14.	35	73	7.	0.	7.	39	49	44.	0.	44.
25	67	17.	0.	17.	32	23	35.	0.	35.	35	81	0.	25.	25.	39	50	4.	0.	4.
25	64	8.	0.	8.	32	27	0.	15.	15.	35	82	10.	6.	16.	39	51	5.	0.	5.
25	65	63.	0.	63.	32	30	1.	0.	1.	35	83	2.	0.	2.	39	52	18.	0.	18.
25	75	3.	0.	3.	32	31	29.	0.	29.	35	84	1.	0.	1.	39	55	8.	0.	8.
25	78	2.	0.	2.	32	32	38.	0.	38.	35	85	7.	0.	7.	39	56	10.	0.	10.
25	81	10.	0.	10.	32	39	20.	0.	20.	35	90	4.	0.	4.	39	57	8.	0.	8.
25	82	2.	0.	2.	32	40	54.	14.	61.	35	91	14.	0.	14.	39	60	10.	0.	10.
26	17	0.	20.	20.	32	41	33.	0.	33.	35	92	6.	0.	6.	39	61	10.	0.	10.
26	18	5.	32.	37.	32	49	12.	0.	12.	36	10	3.	0.	3.	39	62	9.	0.	9.
26	25	11.	1.	12.	32	51	0.	37.	37.	36	11	5.	4.	11.	39	63	3.	0.	3.
26	36	17.	40.	57.	32	53	0.	25.	25.	36	12	7.	0.	7.	39	64	10.	0.	10.
26	37	4.	0.	4.	32	54	43.	0.	43.	36	27	29.	0.	29.	40	21	2.	0.	2.
26	38	49.	0.	49.	32	55	43.	0.	43.	36	28	17.	0.	17.	40	22	24.	0.	24.
26	40	10.	0.	10.	32	59	4.	0.	4.	36	26	4.	0.	4.	40	23	12.	0.	12.
26	41	5.	0.	5.	32	62	9.	0.	9.	36	27	51.	0.	51.	40	29	13.	0.	13.
26	44	9.	0.	9.	32	63	16.	0.	16.	36	35	8.	3.	11.	40	33	15.	5.	20.
26	51	6.	0.	6.	32	65	7.	0.	7.	36	36	17.	7.	10.	40	34	19.	44.	62.
26	52	73.	0.	73.	32	66	82.	3.	85.	36	37	23.	0.	23.	40	35	1.	3.	4.
26	53	16.	0.	16.	32	77	28.	0.	28.	36	38	53.	3.	56.	40	41	50.	0.	50.
26	55	7.	0.	7.	32	78	47.	24.	71.	36	39	40.	0.	40.	40	42	29.	0.	29.
26	62	30.	0.	30.	32	79	50.	0.	50.	36	40	14.	0.	14.	40	43	21.	0.	21.
26	64	18.	0.	18.	32	80	47.	0.	47.	36	41	24.	0.	24.	40	44	27.	0.	27.
27	25	1.	2.	3.	32	81	26.	0.	26.	36	42	39.	29.	68.	40	45	70.	5.	75.
27	30	1.	0.	1.	32	82	10.	0.	10.	36	43	20.	0.	20.	40	46	16.	22.	38.
27	36	10.	30.	40.	32	83	15.	0.	15.	36	44	11.	17.	28.	40	47	24.	0.	24.
27	37	0.	20.	20.	32	84	6.	0.	6.	36	45	10.	0.	10.	40	48	19.	3.	22.
27	42	4.	0.	4.	32	85	23.	28.	51.	36	48	22.	0.	22.	40	49	37.	0.	37.
27	43	4.	0.	4.	32	86	0.	11.	11.	36	49	6.	0.	6.	40	50	58.	0.	58.
27	50	0.	2.	2.	32	87	3.	0.	3.	36	53	7.	0.	7.	40	51	29.	0.	29.
27	51	16.	2.	18.	33	23	6.	0.	6.	36	54	3.	0.	3.	40	52	33.	0.	33.
27	52	30.	0.	30.	33	26	19.	0.	19.	36	57	1.	0.	1.	40	53	24.	0.	24.
27	53	12.	0.	12.	33	27	14.	0.	14.	36	58	2.	0.	2.	40	54	18.	0.	18.
27	55	4.	0.	4.	33	31	10.	0.	10.	36	64	21.	0.	21.	40	55	8.	0.	8.
27	56	40.	0.	40.	33	39	3.	0.	3.	36	65	25.	0.	25.	40	56	4.	0.	4.
27	57	4.	0.	4.	33	40	13.	0.	13.	36	66	12.	0.	12.	40	57	19.	0.	19.
27	60	4.	0.	4.	33	41	55.	5.	60.	36	70	5.	0.	5.	40	60	4.	0.	4.
27	61	27.	0.	27.	33	43	0.	11.	11.	36	71	18.	0.	18.	41	20	7.	0.	7.
27	62	4.	0.	4.	33	44	0.	22.	22.	36	72	25.	0.	25.	41	23	17.	0.	17.
27	80	20.	0.	20.	33	45	8.	0.	8.	36	81	0.	12.	12.	41	29	16.	0.	16.
27	84	1.	0.	1.	33	46	3.	0.	3.	36	82	0.	27.	27.	41	30	21.	0.	21.
28	23	10.	5.	15.	33	47	5.	0.	5.	36	83	3.	20.	23.	41	32	4.	0.	4.
28	24	1.	0.	1.	33	48	5.	0.	5.	36	84	2.	57.	59.	41	33	7.	18.	25.
28	27	0.	4.	4.	33	50	1.	7.	10.	36	85	6.	45.	51.	41	34	39.	30.	69.
28	28	0.	13.	13.	33	51	6.	45.	51.	36	86	0.	7.	7.	41	35			

TABLE A.8 (Contd.)

X	Y	P1+P2	P3	TOTAL	X	Y	P1+P2	P3	TOTAL	X	Y	P1+P2	P3	TOTAL	X	Y	P1+P2	P3	TOTAL
42	41	52.	0.	52.	44	30	22.	0.	22.	46	19	0.	30.	30.	49	13	1.	0.	1.
42	44	34.	0.	34.	44	31	27.	0.	27.	46	20	0.	5.	5.	49	22	5.	0.	5.
42	46	30.	26.	56.	44	32	42.	0.	42.	46	22	62.	12.	74.	49	23	35.	0.	35.
42	47	36.	24.	60.	44	33	66.	0.	66.	46	23	71.	51.	72.	49	28	8.	0.	8.
42	48	35.	0.	35.	44	34	9.	0.	9.	46	24	59.	18.	77.	49	29	41.	0.	41.
42	49	19.	0.	19.	44	35	33.	0.	33.	46	25	19.	0.	19.	49	31	20.	16.	36.
42	50	62.	0.	62.	44	36	15.	0.	15.	46	30	6.	0.	6.	49	32	70.	8.	78.
42	51	3.	0.	3.	44	37	13.	0.	13.	46	31	15.	0.	15.	49	33	12.	30.	42.
42	52	2.	0.	2.	44	38	1.	0.	1.	46	32	18.	2.	20.	49	34	14.	28.	42.
42	53	17.	0.	17.	44	39	13.	0.	13.	46	33	5.	27.	32.	49	35	8.	73.	81.
42	54	44.	0.	44.	44	40	1.	0.	1.	46	34	15.	25.	40.	49	36	1.	99.	100.
42	55	3.	0.	3.	44	41	13.	0.	13.	46	35	0.	65.	65.	49	37	7.	65.	72.
42	58	3.	0.	3.	44	43	6.	0.	6.	46	36	6.	33.	39.	49	38	18.	27.	45.
42	59	9.	0.	9.	44	44	15.	0.	15.	46	37	2.	13.	15.	49	39	33.	1.	34.
42	60	21.	0.	21.	44	45	8.	84.	92.	46	38	14.	17.	31.	49	40	8.	0.	8.
42	61	6.	0.	6.	44	46	17.	25.	42.	46	39	11.	0.	11.	50	23	10.	0.	10.
43	19	6.	0.	6.	44	47	27.	36.	63.	46	41	2.	0.	2.	50	31	4.	10.	14.
43	20	1.	0.	1.	44	48	30.	0.	30.	46	42	24.	0.	24.	50	32	52.	7.	54.
43	22	0.	5.	5.	44	49	36.	0.	36.	46	43	3.	0.	3.	50	33	15.	5.	70.
43	27	7.	0.	7.	44	50	50.	0.	50.	46	44	2.	0.	2.	50	34	18.	9.	26.
43	28	29.	0.	29.	44	51	10.	46.	56.	46	45	5.	0.	5.	50	35	27.	28.	55.
43	29	27.	0.	27.	44	52	25.	30.	55.	46	47	32.	0.	32.	50	36	23.	12.	35.
43	31	9.	0.	9.	44	53	16.	0.	16.	46	48	4.	0.	4.	50	37	10.	6.	16.
43	32	22.	0.	22.	44	54	4.	0.	4.	47	22	39.	0.	39.	50	38	11.	21.	32.
43	33	27.	42.	69.	45	12	2.	0.	2.	47	23	13.	0.	13.	50	39	4.	68.	72.
43	34	12.	0.	12.	45	17	5.	0.	5.	47	24	10.	0.	10.	50	40	6.	54.	60.
43	35	15.	14.	33.	45	19	13.	0.	13.	47	25	9.	0.	9.	61	58	28.	0.	28.
43	36	15.	0.	15.	45	22	37.	47.	84.	47	27	1.	0.	1.					
43	40	6.	0.	6.	45	23	0.	73.	73.	47	28	10.	0.	10.					
43	41	25.	0.	25.	45	24	22.	77.	99.	47	29	22.	0.	22.					
43	42	10.	0.	10.	45	25	17.	11.	28.	47	30	11.	0.	11.					
43	43	34.	0.	34.	45	26	15.	0.	15.	47	32	7.	21.	28.					
43	44	19.	0.	19.	45	27	62.	0.	62.	47	33	0.	24.	24.					
43	45	43.	30.	73.	45	28	73.	0.	73.	47	34	5.	30.	35.					
43	46	8.	4.	12.	45	29	69.	0.	69.	47	35	0.	30.	30.					
43	47	4.	60.	64.	45	30	46.	0.	46.	47	36	0.	14.	14.					
43	48	31.	0.	31.	45	31	16.	0.	16.	47	37	7.	73.	80.					
43	50	41.	0.	41.	45	32	8.	0.	8.	47	38	18.	52.	70.					
43	52	15.	15.	30.	45	33	5.	0.	5.	47	39	30.	0.	30.					
43	53	38.	15.	53.	45	34	1.	36.	37.	47	40	11.	0.	11.					
43	54	5.	0.	5.	45	35	4.	0.	4.	47	41	24.	0.	24.					
43	55	9.	0.	9.	45	36	2.	0.	2.	47	42	3.	0.	3.					
43	56	13.	0.	13.	45	37	6.	0.	6.	48	23	4.	0.	4.					
43	58	7.	0.	7.	45	39	29.	0.	29.	48	28	15.	0.	15.					
43	59	4.	0.	4.	45	40	53.	0.	53.	48	29	49.	0.	49.					
43	60	2.	0.	2.	45	41	13.	0.	13.	48	30	7.	0.	7.					
43	61	5.	0.	5.	45	42	13.	0.	13.	48	31	0.	3.	3.					
44	16	1.	0.	1.	45	43	19.	0.	19.	48	32	3.	57.	55.					
44	21	19.	0.	19.	45	44	46.	0.	46.	48	33	2.	32.	34.					
44	22	12.	31.	43.	45	45	40.	0.	40.	48	34	0.	86.	86.					
44	23	6.	8.	14.	45	46	26.	0.	26.	48	35	0.	59.	59.					
44	24	0.	5.	5.	45	47	28.	0.	28.	48	36	0.	57.	57.					
44	25	3.	0.	3.	45	48	65.	0.	65.	48	37	11.	83.	94.					
44	26	5.	0.	5.	45	49	32.	0.	32.	48	38	24.	24.	48.					
44	27	39.	0.	39.	45	50	45.	0.	45.	48	39	18.	0.	18.					
44	28	49.	0.	49.	45	51	9.	0.	9.	48	40	18.	0.	18.					
44	29	25.	0.	25.	46	18	1.	15.	16.	48	41	1.	0.	1.					

TABLE A.9. I.D. Listing of 1970 Data for Limited, General, and Heavy Manufacturing

ID	M1	M2	M3	AREA	ID	M1	M2	M3	AREA	ID	M1	M2	M3	AREA
10	0.0	0.0	0.0	1.00	580	1.10	0.0	0.05	100.00	1150	0.0	0.0	0.0	1.00
20	5.00	4.00	5.00	1.00	590	1.81	0.0	0.12	100.00	1160	0.0	0.0	0.0	1.00
30	0.0	10.00	46.00	1.00	600	2.27	0.23	0.0	100.00	1170	0.0	0.0	0.0	1.00
40	0.0	0.0	0.0	1.00	610	1.37	0.10	0.0	100.00	1180	0.0	0.0	0.0	1.00
50	3.00	0.0	0.0	1.00	620	3.61	0.0	1.47	100.00	1190	0.0	0.0	0.0	1.00
60	0.0	0.0	0.0	1.00	630	0.29	0.12	0.14	100.00	1200	0.0	0.0	0.0	1.00
70	28.00	17.00	0.0	1.00	640	0.44	0.0	0.0	25.00	1210	0.0	0.0	0.0	1.00
80	15.00	35.00	0.0	1.00	650	4.88	0.24	0.0	25.00	1220	0.0	0.0	0.0	1.00
90	17.00	24.00	0.0	1.00	660	6.16	4.37	0.12	25.00	1230	0.0	0.0	0.0	1.00
100	21.00	41.00	0.0	1.00	670	7.62	2.68	0.40	100.00	1240	0.0	0.0	0.0	1.00
110	0.0	0.0	0.0	1.00	680	4.65	1.56	2.94	100.00	1250	0.0	0.0	0.0	1.00
120	0.0	32.00	0.0	1.00	690	0.60	0.0	0.09	100.00	1260	0.0	0.0	0.0	1.00
130	36.00	0.0	0.0	1.00	700	3.04	4.32	0.0	25.00	1270	0.0	0.0	0.0	1.00
140	0.0	0.0	0.0	1.00	710	5.48	0.12	0.0	25.00	1280	0.0	0.0	0.0	1.00
150	19.00	0.0	0.0	1.00	720	5.12	1.60	0.36	25.00	1290	0.0	0.0	0.0	1.00
160	2.00	2.00	0.0	1.00	730	3.80	0.60	0.0	25.00	1300	0.0	0.0	0.0	1.00
170	3.00	62.00	9.00	1.00	740	7.12	15.80	6.32	25.00	1310	0.0	0.0	0.0	1.00
180	7.00	23.00	0.0	1.00	750	9.20	0.55	0.48	100.00	1320	0.0	0.0	0.0	1.00
190	7.00	24.00	0.0	1.00	760	3.91	3.40	0.79	100.00	1330	0.0	0.0	0.0	1.00
200	18.00	17.00	0.0	1.00	770	0.42	0.06	0.65	100.00	1340	0.0	0.0	0.0	1.00
210	17.00	15.00	0.0	1.00	780	5.56	7.08	0.08	25.00	1350	0.0	0.0	0.0	1.00
220	18.00	10.00	6.00	1.00	790	2.28	2.24	4.20	25.00	1360	4.75	7.75	10.00	4.00
230	9.00	13.00	36.00	1.00	800	5.64	8.52	25.52	25.00	1370	8.00	0.25	3.25	4.00
240	0.0	4.00	60.00	1.00	810	2.80	1.16	7.08	25.00	1380	0.0	14.00	3.00	4.00
250	8.00	28.00	24.00	1.00	820	4.33	0.0	3.13	100.00	1390	0.0	0.0	0.0	4.00
260	0.0	0.0	0.0	1.00	830	2.06	1.17	7.61	100.00	1400	0.0	0.0	0.0	4.00
270	0.0	0.0	0.0	1.00	840	0.25	0.51	2.39	100.00	1410	0.0	0.0	0.0	4.00
280	26.00	0.0	0.0	1.00	850	11.52	2.90	14.20	25.00	1420	0.0	0.0	0.0	4.00
290	6.00	11.00	25.00	1.00	860	4.68	3.76	0.0	25.00	1430	0.0	0.0	0.0	4.00
300	6.00	2.00	4.00	1.00	870	4.88	4.60	6.64	25.00	1440	0.0	0.0	0.0	4.00
310	13.00	17.00	26.00	1.00	880	1.72	8.56	1.60	25.00	1450	0.0	0.0	0.0	4.00
320	1.00	0.0	0.0	4.00	890	3.00	4.44	33.28	25.00	1460	0.0	0.0	0.0	4.00
330	9.00	6.25	0.0	4.00	900	11.72	4.92	9.52	25.00	1470	0.0	0.0	0.0	4.00
340	12.00	0.25	0.0	4.00	910	2.76	0.80	1.64	100.00	1480	0.0	0.0	0.0	4.00
350	7.75	2.50	7.50	4.00	920	1.24	0.38	9.01	100.00	1490	0.0	0.0	0.0	4.00
360	11.25	6.75	7.50	4.00	930	1.68	0.20	5.77	100.00	1500	0.0	0.0	0.0	4.00
370	14.50	5.75	0.0	4.00	940	10.56	8.28	0.76	25.00	1510	0.0	0.0	0.0	4.00
380	13.25	15.25	0.0	4.00	950	4.56	9.20	0.0	25.00	1520	0.0	0.0	0.0	4.00
390	10.75	7.50	0.75	4.00	960	10.04	4.44	11.56	25.00	1530	0.0	0.0	0.0	36.00
400	6.00	8.25	20.75	4.00	970	3.12	0.40	1.56	25.00	1540	0.0	0.0	0.0	100.00
410	1.75	0.0	0.0	4.00	980	1.43	0.46	0.02	100.00	1550	0.40	0.0	0.0	25.00
420	17.50	9.75	21.00	4.00	990	0.74	0.65	2.58	100.00	1560	0.0	0.0	0.0	25.00
430	0.75	23.25	7.50	4.00	1000	0.65	0.31	12.04	100.00	1570	0.0	0.0	0.0	25.00
440	17.75	20.75	16.25	4.00	1010	0.76	0.0	2.00	25.00	1580	0.0	0.0	0.0	25.00
450	0.0	0.0	0.0	4.00	1020	1.64	0.64	0.04	25.00	1590	0.0	0.0	0.0	100.00
460	6.00	1.50	0.0	4.00	1030	0.04	0.0	0.0	100.00	1600	0.0	0.0	0.0	100.00
470	8.50	1.00	0.0	4.00	1040	0.21	0.03	0.06	100.00	1610	0.0	0.0	0.0	100.00
480	4.50	6.50	0.0	4.00	1050	0.0	0.0	0.0	100.00	1620	0.0	0.0	0.0	100.00
490	10.75	2.50	0.0	4.00	1060	0.13	0.0	1.85	100.00	1630	0.0	0.0	0.0	100.00
500	2.50	0.0	30.50	4.00	1070	0.0	0.0	0.0	1.00	1640	0.0	0.0	0.0	100.00
510	5.25	0.0	6.75	4.00	1080	0.0	0.0	0.0	1.00	1650	0.0	0.0	0.0	25.00
520	1.11	1.92	0.33	100.00	1090	0.0	0.0	0.0	1.00	1660	0.0	0.0	0.0	25.00
530	0.22	0.23	0.08	100.00	1100	0.0	0.0	0.0	1.00	1670	0.0	0.0	0.0	4.00
540	0.46	0.0	0.21	100.00	1110	0.0	0.0	0.0	1.00	1680	0.0	0.0	0.0	1.00
550	0.31	0.0	0.08	100.00	1120	0.0	0.0	0.0	1.00	1690	0.0	0.0	0.0	1.00
560	4.27	1.48	3.37	100.00	1130	0.0	0.0	0.0	1.00					
570	1.13	0.0	0.0	100.00	1140	0.0	0.0	0.0	1.00					

TABLE A.10. I.D. Listing of 1970 Data for
Light and Heavy Manufacturing

ID	M1+M2	M3	AREA	ID	M1+M2	M3	AREA	ID	M1+M2	M3	AREA
10	0.0	0.0	1.00	580	1.10	0.05	100.00	1150	0.0	0.0	1.00
20	9.00	5.00	1.00	590	1.81	0.12	100.00	1160	0.0	0.0	1.00
30	10.00	46.00	1.00	600	2.50	0.0	100.00	1170	0.0	0.0	1.00
40	0.0	0.0	1.00	610	1.47	0.0	100.00	1180	0.0	0.0	1.00
50	3.00	0.0	1.00	620	3.61	1.47	100.00	1190	0.0	0.0	1.00
60	0.0	0.0	1.00	630	0.41	0.14	100.00	1200	0.0	0.0	1.00
70	45.00	0.0	1.00	640	0.44	0.0	25.00	1210	0.0	0.0	1.00
80	50.00	0.0	1.00	650	5.12	0.0	25.00	1220	0.0	0.0	1.00
90	41.00	0.0	1.00	660	10.48	0.12	25.00	1230	0.0	0.0	1.00
100	62.00	0.0	1.00	670	10.30	0.40	100.00	1240	0.0	0.0	1.00
110	0.0	0.0	1.00	680	6.21	2.94	100.00	1250	0.0	0.0	1.00
120	32.00	0.0	1.00	690	0.60	0.09	100.00	1260	0.0	0.0	1.00
130	36.00	0.0	1.00	700	7.36	0.0	25.00	1270	0.0	0.0	1.00
140	0.0	0.0	1.00	710	5.60	0.0	25.00	1280	0.0	0.0	1.00
150	19.00	0.0	1.00	720	6.72	0.36	25.00	1290	0.0	0.0	1.00
160	4.00	0.0	1.00	730	4.40	0.0	25.00	1300	0.0	0.0	1.00
170	65.00	9.00	1.00	740	22.92	6.32	25.00	1310	0.0	0.0	1.00
180	30.00	0.0	1.00	750	9.75	0.48	100.00	1320	0.0	0.0	1.00
190	31.00	0.0	1.00	760	7.31	0.79	100.00	1330	0.0	0.0	1.00
200	35.00	0.0	1.00	770	0.48	0.65	100.00	1340	0.0	0.0	1.00
210	32.00	0.0	1.00	780	12.64	0.08	25.00	1350	0.0	0.0	1.00
220	28.00	6.00	1.00	790	4.52	4.20	25.00	1360	12.50	10.00	4.00
230	27.00	36.00	1.00	800	14.16	25.52	25.00	1370	8.25	3.25	4.00
240	4.00	60.00	1.00	810	3.96	7.08	25.00	1380	14.00	3.00	4.00
250	36.00	24.00	1.00	820	4.33	3.13	100.00	1390	0.0	0.0	4.00
260	0.0	0.0	1.00	830	3.23	7.61	100.00	1400	0.0	0.0	4.00
270	0.0	0.0	1.00	840	0.76	2.39	100.00	1410	0.0	0.0	4.00
280	26.00	0.0	1.00	850	14.32	14.20	25.00	1420	0.0	0.0	4.00
290	17.00	25.00	1.00	860	8.44	0.0	25.00	1430	0.0	0.0	4.00
300	8.00	4.00	1.00	870	9.48	6.64	25.00	1440	0.0	0.0	4.00
310	30.00	26.00	1.00	880	10.28	1.60	25.00	1450	0.0	0.0	4.00
320	1.00	0.0	4.00	890	7.44	33.28	25.00	1460	0.0	0.0	4.00
330	15.25	0.0	4.00	900	16.64	9.52	25.00	1470	0.0	0.0	4.00
340	12.25	0.0	4.00	910	3.56	1.64	100.00	1480	0.0	0.0	4.00
350	10.25	7.50	4.00	920	1.62	9.01	100.00	1490	0.0	0.0	4.00
360	18.00	7.50	4.00	930	1.88	5.77	100.00	1500	0.0	0.0	4.00
370	20.25	0.0	4.00	940	18.84	0.76	25.00	1510	0.0	0.0	4.00
380	28.50	0.0	4.00	950	13.76	0.0	25.00	1520	0.0	0.0	4.00
390	18.25	0.75	4.00	960	14.48	11.56	25.00	1530	0.0	0.0	36.00
400	14.25	20.75	4.00	970	3.52	1.96	25.00	1540	0.0	0.0	100.00
410	1.75	0.0	4.00	980	1.85	0.02	100.00	1550	0.40	0.0	25.00
420	27.25	21.00	4.00	990	1.39	2.58	100.00	1560	0.0	0.0	25.00
430	24.00	7.50	4.00	1000	0.96	12.04	100.00	1570	0.0	0.0	25.00
440	38.50	16.25	4.00	1010	0.76	2.00	25.00	1580	0.0	0.0	25.00
450	0.0	0.0	4.00	1020	2.28	0.04	25.00	1590	0.0	0.0	100.00
460	7.50	0.0	4.00	1030	0.04	0.0	100.00	1600	0.0	0.0	100.00
470	9.50	0.0	4.00	1040	0.24	0.06	100.00	1610	0.0	0.0	100.00
480	11.00	0.0	4.00	1050	0.0	0.0	100.00	1620	0.0	0.0	100.00
490	13.25	0.0	4.00	1060	0.13	1.85	100.00	1630	0.0	0.0	100.00
500	2.50	30.50	4.00	1070	0.0	0.0	1.00	1640	0.0	0.0	100.00
510	5.25	6.75	4.00	1080	0.0	0.0	1.00	1650	0.0	0.0	25.00
520	3.03	0.33	100.00	1090	0.0	0.0	1.00	1660	0.0	0.0	25.00
530	0.45	0.08	100.00	1100	0.0	0.0	1.00	1670	0.0	0.0	4.00
540	0.46	0.21	100.00	1110	0.0	0.0	1.00	1680	0.0	0.0	1.00
550	0.31	0.08	100.00	1120	0.0	0.0	1.00	1690	0.0	0.0	1.00
560	5.75	3.37	100.00	1130	0.0	0.0	1.00				
570	1.13	0.0	100.00	1140	0.0	0.0	1.00				

The final listing (Table A.11) is the 1964 zoning survey. This survey was incomplete. Two major areas not included in the survey were Will County and Chicago. In addition, only two zoning classes were considered. They are M1 = light manufacturing and M2 = heavy manufacturing. The M3 class represents the portion of a source left unzoned because of the incomplete nature of the survey.

A meaningful comparison between the 1970 and the 1964 surveys for the area outside Will County and Chicago could not be made on a square-mile basis because of grid-alignment errors. Therefore, only a source I.D. comparison (including 40 sources) was performed. Of the 40 sources, eight, six, and seven had changes of greater than 2% i.e., $|M(1970) - M(1964)| > 2\%$, for light, heavy, and total manufacturing, respectively. This represents a maximum of 20% of the sources showing any change in industrial zoning. It was assumed that a change of greater than 2% represented an actual change and not a statistical variation.

In addition, only 5% of the sources showed changes of greater than 10% in industrial zoning, and none showed changes greater than 15%. Considering the fact that the industrial zoning in Chicago has not changed greatly over the six-year period, the total percent changes in zoning would be even smaller.

One important assumption used while making the comparison should be mentioned. If the incomplete portion of any source in the 1964 survey could account for the difference in the two surveys, it was assumed that no change occurred.

These results indicate that a zoning inventory of this type does not become obsolete in a short period of time, even though zoning ordinances are constantly being revised. Therefore this type of zoning inventory represents a useful tool for long-range planning.

TABLE A.11. I.D. Listing of 1964 Data

ID	M1	M2	M3	AREA	ID	M1	M2	M3	AREA	ID	M1	M2	M3	AREA
10	0.0	0.0	0.0	1.00	580	1.37	0.11	1.34	100.00	1150	0.0	0.0	0.0	1.00
20	0.0	0.0	0.0	1.00	590	1.01	0.08	3.13	100.00	1160	0.0	0.0	0.0	1.00
30	0.0	0.0	0.0	1.00	600	2.67	0.0	22.52	100.00	1170	0.0	0.0	0.0	1.00
40	0.0	0.0	0.0	1.00	610	1.94	0.0	1.77	100.00	1180	0.0	0.0	0.0	1.00
50	0.0	0.0	0.0	1.00	620	2.70	1.27	4.25	100.00	1190	0.0	0.0	0.0	1.00
60	0.0	0.0	0.0	1.00	630	5.16	0.38	3.02	100.00	1200	0.0	0.0	0.0	1.00
70	0.0	0.0	0.0	1.00	640	6.44	0.0	0.0	25.00	1210	0.0	0.0	0.0	1.00
80	0.0	0.0	0.0	1.00	650	6.16	0.0	0.0	25.00	1220	0.0	0.0	0.0	1.00
90	0.0	0.0	0.0	1.00	660	0.76	0.24	0.0	25.00	1230	0.0	0.0	0.0	1.00
100	0.0	0.0	0.0	1.00	670	5.78	3.66	0.23	100.00	1240	0.0	0.0	0.0	1.00
110	0.0	0.0	0.0	1.00	680	3.69	4.99	0.0	100.00	1250	0.0	0.0	0.0	1.00
120	0.0	0.0	0.0	1.00	690	0.45	0.01	0.0	100.00	1260	0.0	0.0	0.0	1.00
130	0.0	0.0	0.0	1.00	700	4.20	3.12	6.52	25.00	1270	0.0	0.0	0.0	1.00
140	0.0	0.0	0.0	1.00	710	5.96	0.68	0.0	25.00	1280	0.0	0.0	0.0	1.00
150	0.0	0.0	0.0	1.00	720	11.24	6.52	0.0	25.00	1290	0.0	0.0	0.0	1.00
160	0.0	0.0	0.0	1.00	730	1.08	0.0	16.12	25.00	1300	0.0	0.0	0.0	1.00
170	0.0	0.0	0.0	1.00	740	13.08	2.56	16.44	25.00	1310	0.0	0.0	0.0	1.00
180	0.0	0.0	0.0	1.00	750	3.13	0.43	1.10	100.00	1320	0.0	0.0	0.0	1.00
190	0.0	0.0	0.0	1.00	760	7.72	3.30	0.77	100.00	1330	0.0	0.0	0.0	1.00
200	0.0	0.0	0.0	1.00	770	0.52	0.32	0.0	100.00	1340	0.0	0.0	0.0	1.00
210	0.0	0.0	0.0	1.00	780	1.36	1.04	5.32	25.00	1350	0.0	0.0	0.0	1.00
220	0.0	0.0	0.0	1.00	790	1.38	2.92	19.92	25.00	1360	0.0	0.0	0.0	4.00
230	0.0	0.0	0.0	1.00	800	3.64	14.84	28.72	25.00	1370	0.0	0.0	0.0	4.00
240	0.0	0.0	0.0	1.00	810	3.98	2.94	17.24	25.00	1380	0.0	0.75	1.50	4.00
250	0.0	0.0	0.0	1.00	820	1.44	1.30	0.0	100.00	1390	0.0	0.0	0.0	4.00
260	0.0	0.0	0.0	1.00	830	1.67	7.32	1.29	100.00	1400	0.0	0.0	0.0	4.00
270	0.0	0.0	0.0	1.00	840	2.27	1.94	0.91	100.00	1410	0.0	0.0	0.0	4.00
280	0.0	0.0	0.0	1.00	850	0.0	0.0	0.0	25.00	1420	0.0	0.0	0.0	4.00
290	0.0	0.0	0.0	1.00	860	0.20	0.0	25.60	25.00	1430	0.0	0.0	0.0	4.00
300	0.0	0.0	0.0	1.00	870	4.18	3.40	19.08	25.00	1440	0.0	0.0	0.0	4.00
310	0.0	0.0	0.0	1.00	880	11.04	4.84	2.90	25.00	1450	0.0	0.0	0.0	4.00
320	0.0	0.0	0.0	4.00	890	1.54	4.04	5.44	25.00	1460	0.0	0.0	45.00	4.00
330	0.0	0.0	0.0	4.00	900	3.36	10.29	49.58	25.00	1470	0.0	0.0	0.0	4.00
340	0.0	0.0	0.0	4.00	910	2.37	2.34	3.06	100.00	1480	0.0	0.0	0.0	4.00
350	0.0	0.0	0.0	4.00	920	0.51	2.63	0.34	100.00	1490	0.0	0.0	0.0	4.00
360	0.0	0.0	0.0	4.00	930	0.0	0.0	0.0	100.00	1500	0.0	0.0	0.0	4.00
370	0.0	0.0	0.0	4.00	940	6.40	9.69	28.69	25.00	1510	0.0	0.0	0.0	4.00
380	0.0	0.0	0.0	4.00	950	3.00	3.92	33.96	25.00	1520	0.0	0.0	0.0	4.00
390	0.0	0.0	0.0	4.00	960	5.88	15.20	5.08	25.00	1530	0.0	0.0	0.0	36.00
400	0.25	4.00	20.75	4.00	970	8.30	0.29	3.84	25.00	1540	0.0	0.0	0.0	100.00
410	0.0	0.0	0.0	4.00	980	0.16	0.0	0.0	100.00	1550	2.28	0.0	1.60	25.00
420	0.0	0.0	0.0	4.00	990	0.0	0.0	0.0	100.00	1560	0.0	0.0	0.0	25.00
430	0.0	0.0	0.0	4.00	1000	0.0	0.0	0.0	100.00	1570	0.0	0.0	0.0	25.00
440	0.25	5.75	19.00	4.00	1010	0.0	0.0	0.0	25.00	1580	0.0	0.0	0.0	25.00
450	0.0	0.0	0.0	4.00	1020	0.20	0.0	0.0	25.00	1590	0.0	0.0	0.0	100.00
460	0.0	0.0	0.0	4.00	1030	0.0	0.0	0.0	100.00	1600	0.0	0.0	0.0	100.00
470	0.0	0.0	0.0	4.00	1040	0.0	0.0	0.0	100.00	1610	0.0	0.0	0.0	100.00
480	0.0	0.0	0.0	4.00	1050	0.0	0.0	0.0	100.00	1620	0.0	0.0	0.0	100.00
490	0.0	0.0	0.0	4.00	1060	0.0	0.0	0.0	100.00	1630	0.0	0.0	0.0	100.00
500	0.0	0.0	0.0	4.00	1070	0.0	0.0	0.0	1.00	1640	0.0	0.0	0.0	100.00
510	0.0	0.0	0.0	4.00	1080	0.0	0.0	0.0	1.00	1650	0.0	0.0	0.0	25.00
520	0.34	0.28	6.46	100.00	1090	0.0	0.0	0.0	1.00	1660	0.0	0.0	0.0	25.00
530	0.41	0.0	1.10	100.00	1100	0.0	0.0	0.0	1.00	1670	0.0	0.0	0.0	4.00
540	0.14	0.14	0.46	100.00	1110	0.0	0.0	0.0	1.00	1680	0.0	0.0	0.0	1.00
550	0.10	0.06	0.52	100.00	1120	0.0	0.0	0.0	1.00	1690	0.0	0.0	0.0	1.00
560	2.07	1.19	9.38	100.00	1130	0.0	0.0	0.0	1.00					
570	1.37	0.01	4.13	100.00	1140	0.0	0.0	0.0	1.00					

APPENDIX B

Computer Program Descriptions

(J. S. Stork)

B.I. DOCUMENTATION OF PROGRAM POLUT

B.I.1 Overview

The purpose of the POLUT program is to calculate the emission density and emissions either SO₂ or particulate, controlled or uncontrolled on a square mile basis. The emissions are normally of two types, i.e., point sources and area sources. The latter are found distributed in the variable mesh IPP grid. The actual method used is to subdivide the large IPP grid squares into smaller unit squares, each of which is one square mile in area. Then the desired point emissions are accumulated in the unit squares in which they lie, while the area emissions are distributed through all of the unit squares which lie in each IPP grid square. After all required emissions have been accumulated, the unit squares are ordered by emissions, and later by emission densities. Then a selected number of the largest are printed out.

Four different types or classes of emission may be investigated, they are:

- 1) Heavy Industry--all point sources are accumulated, except power plants (SIC 4911) and residential office buildings (SIC-99XY).
- 2) Residential Commercial--a percentage of each area source is accumulated as well as the residential office buildings (SIC-99XY).
- 3) Light Industry--a percentage of each area source is accumulated.
- 4) Total--the sum of items 1, 2, and 3 above for each square.

A percentage P_J is associated with each area source to indicate how much of the area emissions put in E_J from that source is to be considered as residential commercial. The balance of the emissions are then considered to be due to light industry. The emissions E_{ij}^I are distributed into the unit squares S_{ij} from the IPP square by calculating

$$E_{ij}^I = \frac{\hat{P}_J^I E_J^I Z_{ij}^I}{100 \sum_{i,j} Z_{ig}^I},$$

where

I is class 2 or 3,

J is the area source number of IPP square S_J ,

i, j assume all values which place unit squares S_{ij} into IPP square S_J ,

Z_{ij}^I is the class zoning inventory for square S_{ij} expressed as a fraction,

$\hat{P}_J^I$ is the class percentage, i.e., P_J for $I=2$ and $100-P_J$ for $I=3$.

Thus, if Z_{ij}^I is zero for a particular class, a convention has been established that the emissions accumulated for that class in square S_{ij} shall be zero regardless of the class or actual emissions accumulated. This is a necessity since the emission density (ED_{ij}^I) per unit square S_{ij} is calculated as $ED_{ij}^I = E_{ij}^I / Z_{ij}^I$. Finally, the emissions in any particular political jurisdiction can be investigated separately.

With each investigation the mean and standard deviation are also given.

B.I.2 Input

Three different data sets are used as input to POLUT. Listed with their data set reference numbers, in the order in which the data sets are first accessed, they are defined below.

1. FT13F001--INSORC binary input--read in MAIN program.

This data set contains the data read by the AQDM name-list INSORC.

2. FT05F001--Formatted card input--read in MAIN program.

This data set contains the control cards that determine which cases will be investigated. Each input card represents one set of cases. The data appearing on each card is defined below. Several of these cards can be used together in one computer run.

<u>Variable</u>	<u>Type</u>	<u>Columns</u>	<u>Definition</u>
EPS	R*4	1-10	When printing the output, EPS represents the lowest cumulative emissions that are of interest and should be printed.

<u>Variable</u>	<u>Type</u>	<u>Columns</u>	<u>Definition</u>
IPOLUT	I*4	11-15	Uncontrolled investigation = IPOLUT { 0--No investigation 1--SO ₂ only 2--Particulate only 3--Both SO ₂ and particulate
JPOLUT	I*4	16-20	Controlled investigation = JPOLUT { 0--No investigation 1--SO ₂ only 2--Particulate only 3--Both SO ₂ and particulate
NEMISS	I*4	21-25	Maximum number of unit squares to be ordered by emissions and printed.
ICLASS	I*4	26-30	Source class to be investigated ICLASS { 1--Heavy industry 2--Residential commercial 3--All sources 4--Light industry
JURISD	I*4	31-35	Political jurisdiction to be investigated. JURISD=0 implies that all political jurisdictions should be allowed simultaneously.
DELTAE	R*4	61-70	Used by the histogram section of the code to space emissions. (This section of the program cannot presently be used.)

3. FT15F001--Formatted Zoning Inventory input--read in subroutine Table 1 from disk.

This data set contains the zoning inventories for each class and unit square. All zoning inventories are given as percentages. The data appearing on each card is defined below.

<u>Variable</u>	<u>Type</u>	<u>Columns</u>	<u>Definition</u>
IX	I*4	1-8	X-coordinate of the lower left-hand corner of the square.
IY	I*4	9-16	Y-coordinate of the lower left-hand corner of the square.
ZT	R*4	17-24	Total zoning in this square.
ZLI	R*4	25-32	Light industry zoning (combined with ZGI and called the zoning inventory for LI).
ZGI	R*4	33-40	General industry zoning (combined with ZLI above).

<u>Variable</u>	<u>Type</u>	<u>Columns</u>	<u>Definition</u>
ZHI	R*4	41-48	Heavy industry zoning.
ZLRC	R*4	49-56	Light residential commercial zoning (not used).
ZGRC	R*4	57-64	General residential commercial zoning (not used).
ZHRC	R*4	65-72	Heavy residential commercial zoning.

Note that the zoning for all squares is originally initialized to zero and hence should some squares not have a zoning card input the program will still run and give zero zoning for all classes.

B.I.3 Program Documentation

The program POLUT consists entirely of one main program and one subroutine--Table 1. The function of the main program is to read data, allocate storage and then call Table 1 to perform the actual calculations. Due to the inherent simplicity of the main program, only subroutine Table 1 will be documented.

B.I.3.1 Arguments (in order)

<u>Variable Name</u>	<u>Type</u>	<u>Dimensions</u>	<u>Significance or Use</u>
SOURCE	R*4	(7,NSORCE)	Contains the AQDM array SORCE.
CSORCE	R*4	(14,NSORCE)	Contains the AQDM array CSORCE.
EMISS	R*4	(IMAX,JMAX)	Holds the emission or the emission density calculated in Table 1.
PERRC	R*4	(250)	Contains the percentages for the area sources of the emission for each IPP square that is due to residential commercial activity.

<u>Variable Name</u>	<u>Type</u>	<u>Dimensions</u>	<u>Significance or Use</u>
IORDER	I*2	(IMAX,JMAX)	Array used to contain the ordered emission indexes.
IPLANT	I*2	NSORCE	IPLANT(N) points to the unit grid square that contains point source N. This is used to determine which point sources in the class under investigation emit into the individual unit squares. If IPLANT(N) is zero, then the point source does not have any emissions.
EPS	R*4	-	See EPS on data set FT05F001.
PLUME	R*4	(3,NSORCE)	Contains the AQDM array PLUME.
NEMISS	I*4	-	See NEMISS on data set FT05F001.
NSORCE	I*4	-	Number of emission sources.
IPOLUT	I*4	-	See IPOLUT on data set FT05F001.
JPOLUT	I*4	-	See JPOLUT on data set FT05F001.
ICLASS	I*4	-	See ICLASS on data set FT05F001.
IMAX	I*4	-	Number of unit squares in the horizontal direction.
JMAX	I*4	-	Number of unit squares in the vertical direction.
DELTA E	R*4	-	See DELTAE on data set FT05F001.
LZONE	I*4	-	Data set reference number upon which the zoning inventories reside.
ZONE	R*4	(IMAX,JMAX)	Zoning inventories for each unit square.
ISRCNM	I*2	(IMAX,JMAX)	ISRCNM(I,J) is the number of the area source which contains square S_{ij} .
JURISD	I*4	-	See JURISD on data set FT05F001.

B.I.3.2 Important Local Variables

<u>Variable Name</u>	<u>Type</u>	<u>Dimensions</u>	<u>Significance or Use</u>
IP	I*4	-	Uncontrolled emission type being investigated (0--no investigation), (1--SO ₂ only), (2--particulate only).

<u>Variable Name</u>	<u>Type</u>	<u>Dimensions</u>	<u>Significance or Use</u>
JP	I*4	-	Controlled emission type being investigated.
IWANT	I*4	-	Index pointing to desired emission.
IZONE	I*4	-	Set to zero initially and changed to one when array EMISS contains emission densities.
IASORC	I*4	-	Number of area sources.
X	R*4	-	Horizontal coordinate of emission source plus 1 mile.
Y	R*4	-	Vertical coordinate of emission source plus 1 mile.
NAREA	I*4	-	Area of emitter in square miles.
SORCEN	R*4	-	SIC number for the emission source.
MILEX	I*4	-	Horizontal coordinate of emission source IPP square plus 1 mile.
MILEY	I*4	-	Vertical coordinate of emission source IPP square plus 1 mile.
NLONG	I*4	-	Length of one side of the IPP square under consideration.
PERCT	R*4	-	Percentage of emissions due to the investigating class. (Either LI or R/C.)
SUM	R*4	-	Total amount of land zoned for this class in the IPP square.
POLUT	R*4	-	Emissions in the area source square due to this class.
TOTALE	R*4	-	Total emissions for this class over the entire region.
NMAX	I*4	-	Number of squares to be ordered.
NUMBER	I*4	-	Number of point sources.
IPOINT	I*4	-	Index of a temporary emission maximum.
JPOINT	I*4	-	Index of a candidate for temporary emission maximum.
CPERCT	R*4	-	Cumulative percentage of all emissions printed to this point.
CZONE	R*4	-	Cumulative fraction of all zoned land printed to this point.

<u>Variable Name</u>	<u>Type</u>	<u>Dimensions</u>	<u>Significance or Use</u>
RPERCT	R*4	-	Percentage of total emissions contained in this square.
POLUTE	R*4	-	Cumulative emissions or emission density in the unit square.
ISTORE	R*4	-	An index for the unit squares when printing out the accumulated emission data.
EMSSDN	R*4	-	Cumulative emission density in the unit square.
ZONINV	R*4	-	Zoning inventory for the unit square.
IFLAG	I*4	-	Counter for the point sources emitting into each square.
TAVE	R*4	-	Average emissions for NMAX unit squares or less.
TA	R*4	-	Number of unit squares under consideration.
SD	R*4	-	Standard deviation for TA unit squares.

B.II. DOCUMENTATION OF PROGRAM SMOG

B.II.1 Overview

The purpose of the SMOG program is to calculate the air quality of the Chicago region at a fixed set of receptor points. The actual receptor points used are not important as long as they are consistent with the calculation of the coupling coefficients from AQDM. The computation for the air quality at receptor $\hat{\chi}_k$ is performed as follows:

$$\hat{\chi}_k = \underbrace{\sum_{m=1}^6 \left\{ \beta_1 E_m \sum_l \alpha_{lm}^k F_{lm} A_l \right\}}_{w_{mk}} + \underbrace{\beta_2 \sum_j \gamma_{jk} P_j}_{w_{7k}}, \quad (1)$$

where

$m = 1$ for Heavy Industry (HI)

$m = 2$ for Light Industry (LI)

$m = 3$ for Heavy Residential/Commercial (HRC)

$m = 4$ for Medium Industry (MI)

$m = 5$ for Medium Residential/Commercial (MRC)

$m = 6$ for Light Residential/Commercial (LRC)

where

E_m is the emission density factor for class m

F_{lm} is the percentage of land zoned for class m in AQDM area source l

A_l is the area of the area source l in square kilometers

α_{lm}^k is the AQDM model area square "coupling" coefficient for class m receptor k ($\alpha_{lj}^k = \alpha_{li}^k$ for $i = 1$ and $j = 3$ also for $i = 2$ and $j = 4, 5, 6$)

P_j is the power plant emissions

γ_{jk} is the AQDM model power plant coupling coefficients

β_2 is the conversion factor $1.05(10)^7$

β_1 is the conversion factor $10.5(62.14)^2 = \beta_2(0.6214)^2/100$.

After computing the components used in Eq. 1, the air quality at receptor $\hat{\chi}_k$ can be expressed as

$$\chi_k = \sum_{m=1}^7 w_{mk}$$

These contributions are normalized and then each of the contributions w_{mk} is printed out for each receptor $\hat{\chi}_k$, as well as the value of χ_k and the standard value for that receptor. This standard is a constant for all receptors and depends only upon the pollutant involved and the status of the emitters, i.e., controlled or uncontrolled.

B.II.2 Input

Six different data sets are used as input to SMOG. Listed with their data set reference numbers, in the order in which the data sets are first accessed, they are defined below:

1. FT12F001--NAMELIST Card input--read in subroutine GRID.

This data set contains the data read by the AQDM namelist INDATA. The input defines the receptor grid and gives calibration information to the program.

2. FT13F001--binary input--read in MAIN program.

This data set contains the data read by the AQDM namelist INSORC. The only point sources are power plants which appear first in the SORCE, CSORCE and PLUME arrays. The power plant sources are then followed by area sources, two area sources for each IPP grid square. Thus, if there are J IPP area sources, the power plant sources are followed by 2J area sources. The first J area sources have their emissions calculated as the total emissions of all point sources (exclusive of SIC 99xy and 4911) in the respective IPP square. The second J area sources have their emissions calculated as the sum of all SIC 99xy emissions in that IPP square.

3. FT05F001--FORMATTED CARD input--read in MAIN program.

This data set contains the zoning inventories for each IPP area source. The order in which these cards appear must agree with the order of the area sources in the INSORC data set. One card for each IPP area source square must be used or an error will result. The data appearing on each card is defined below.

<u>Variable</u>	<u>Type</u>	<u>Columns</u>	<u>Definitions</u>
F _{l,2}	R*4	6-13	Zoning inventory for light industry.
F _{l,4}	R*4	14-20	Zoning inventory for medium industry.
F _{l,1}	R*4	21-27	Zoning inventory for heavy industry.
A _l	R*4	28-34	Area of the square in miles.
F _{l,6}	R*4	35-41	Zoning inventory for light R/C.
F _{l,5}	R*4	42-48	Zoning inventory for medium R/C.
F _{l,3}	R*4	49-55	Zoning inventory for heavy R/C.

4. FT05F002--FORMATTED CARD input--read in MAIN program.

This data set contains the emission density factors, receptor maximum emissions, standard and the emission class. Each input card represents the required input data for one complete calculation. The data which appears on each card is defined below. Using several cards allows several cases to run.

<u>Variable</u>	<u>Type</u>	<u>Columns</u>	<u>Definition</u>
EI	R*4	1-7	Heavy industry emission density factor.
EMI	R*4	8-14	Medium industry emission density factor.
ELI	R*4	15-21	Light industry emission density factor.

<u>Variable</u>	<u>Type</u>	<u>Columns</u>	<u>Definition</u>
ERC	R*4	22-28	Heavy R/C emission density factor.
EMRC	R*4	29-35	Medium R/C emission density factor.
ELRC	R*4	36-42	Light R/C emission density factor.
STAND	R*4	43-49	Standard, not to be exceeded at a receptor.
JPOLUT	I*4	50-55	Calculation class 1--SO ₂ uncontrolled 2--PART uncontrolled 3--SO ₂ controlled 4--PART controlled.

5. FT14F001--binary input--read in subroutine Table 2.

This data set contains the AQDM generated coupling coefficients generated from the INSORC data (item 2 above) for SO₂ emissions.

6. FT15F001--binary input--read in subroutine Table 2.

This data set contains the AQDM generated coupling coefficients generated from the INSORC data (item 2 above) for PARTICULATE emissions.

B.II.3 Program Documentation

The program SMOG consists entirely of one main program and two subroutines. The main program's function is to read in data, allocate storage and then call the subroutines to perform the actual calculations. Subroutine GRID consists of coding lifted from the AQDM program and made into a subroutine. GRID computes the receptor coordinates and stores calibration data. Due to the inherent simplicity of the main program and subroutine GRID, no documentation will be provided for them. Instead, the documentation will center upon the remaining subroutine Table 2.

B.II.3.1 Arguments (in order)

<u>Variable</u>	<u>Dimensions</u>	<u>Type</u>	<u>Significance or Use</u>
RECEP	(2,NRECEP)	R*4	Receptor coordinates: for receptor number L x-coordinate is RECEP(1,L) y-coordinate in RECEP(2,L)
FI	(IASORC)	R*4	Heavy industry zoning inventory
FLI	(IASORC)	R*4	Light industry zoning inventory
AR	(NSORCE)	R*4	All coupling coefficients

SUBROUTINE TABLE 2

<u>Variable Name</u>	<u>Dimensions</u>	<u>Type</u>	<u>Significance or Use</u>
SOURCE	(7,NSORCE)	R*4	Contains the emission source data array SOURCE.
CSORCE	(14,NSORCE)	R*4	Contains the emission source data array CSORCE
RKR	(7,NRECEP)	R*4	Contains the emission contributions from each class to the air quality at each receptor L RKR(1,L) is the power plant contribution RKR(2,L) is the heavy industry contribution RKR(3,L) is the light industry contribution RKR(4,L) is the heavy R/C contribution RKR(5,L) is the medium industry contribution RKR(6,L) is the medium R/C contribution RKR(7,L) is the light R/C contribution

<u>Variable Name</u>	<u>Dimensions</u>	<u>Type</u>	<u>Significance or Use</u>
IDSRN	(4)	I*4	Contains the data set reference numbers for the coupling coefficients SO2--uncontrolled--IDSRN(1) PARTICULATE--uncontrolled--IDSRN(2) SO2--controlled--IDSRN(3) PARTICULATE--controlled--IDSRN(4)
IPLANT	(ICOUNT)	I*2	Indicates the location of the power plants in the SOURCE array. If IPLANT(J)=N>0 then N is a power plant. This is a carryover from an older version of this program.
FRC	(IASORC)	R*4	Heavy R/C zoning inventory
FMI	(IASORC)	R*4	Medium industry zoning inventory
FMRC	(IASORC)	R*4	Light R/C zoning inventory
EMI		R*4	Emission density factor for medium industry
EMRC		R*4	Emission density factor for medium R/C
ELRC		R*4	Emission density factor for light R/C
STAND		R*4	Maximum allowable detected emissions on any receptor
EI		R*4	Emission density factor for heavy industry
ELI		R*4	Emission density factor for light industry
ERC		R*4	Emission density factor for heavy R/C
NRECEP		I*4	Number of receptors
IASORC		I*4	Number of area sources supplied with zoning inventories
NSORCE		I*4	Number of emission sources (2*IASORC+ICOUNT)
IPOLUT		I*4	Calculate type: 1--SO2--uncontrolled 2--PARTICULATE--uncontrolled 3--SO2--controlled 4--PARTICULATE--controlled

B.II.3.2 Important Local Variables

<u>Variable Name</u>	<u>Type</u>	<u>Significance or Use</u>
IATEMP	I*4	Contains the input value of IASORC

<u>Variable Name</u>	<u>Type</u>	<u>Significance or Use</u>
IDSN	I*4	The data set reference number where the coupling coefficients are found
IWANT	I*4	Index to locate proper power plant emissions
CFACT	R*4	Conversion factor $10.5(62.14)^2$ i.e., β_1
IPP	I*4	Calibration index value
IASORC	I*4	Half of the number of area sources in the SOURCE array. Should agree with IATEMP.
NUMBER	I*4	Location of the first area source in the SOURCE array. All $2*IASORC$ area sources are listed consecutively.
IFUDGE	I*4	$(1-NUMBER)$ Aids in indexing the zoning inventories
NSORFX	I*4	Then end of the heavy industry IPP area sources
POLUT	R*4	Power plant emissions
FACTi	R*4	Zoning inventory for class i in an IPP square
RCALC	R*4	For each area source I in class 1 and 3; $\alpha_{I1}A_i\beta_1$
RCALC2	R*4	For each area source I in class 2, 4, 5, and 6; $\alpha_{I2}A_i\beta_1$
RKi	R*4	Evaluated for each receptor I and each class. For $i = 1$; $\beta_2 \sum_j \gamma_{ji}P_j$. For $i = 2, \dots, 7$; $\beta_1 E_i \sum_l \alpha_{li}^I F_{li} A_l$. Later the numbers RKi are normalized as $RKi = RKi(\text{comp}/\text{sum})$
SUM	R*4	$\sum_{i=1}^7 RKi$ where RKi are unnormalized
AC(2,2)	R*4	Calibration correction factors from AQDM calibration runs
BC(2,2)	R*4	
BACKGR	R*4	Pollution background levels for SO_2 and particulate, respectively

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